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FASTNESS CHARACTERISTICS OF NATURAL DYES EXTRACTED FROM JUGLANS REGIA L. AND PUNICA GRANATUM L.: DYEING PROBES & HEAVY METAL TOXICITY ERADICATION

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Abstract: Natural colors are being explored as an "eco-solution" to the problems posed by synthetic dyes. To pander to the environmentally conscious consumer, Indian textile exporters have embraced the use of natural dyes. The standardization of extraction and application techniques for natural color has emerged as an intriguing area of contemporary scientific research. Considering this propensity, it is vital to ensure that natural dyes are ecologically sound. Current work investigates the environmental friendliness of natural dyes encompassing walnut and pomegranate. To establish the eco-friendliness of natural dyes, the test results were compared to the set eco-parameters. In certain instances, the metal toxicity in wastewater effluent and eradication of the assessed toxicity employing a low-cost natural material (*Azadirachta indica* and *Ocimum tenuiflorum*) was additionally examined. It is worth noting that the usage of dried leaves of *Azadirachta indica* (Neem) and *Ocimum tenuiflorum* (Tulsi) in considerable quantities may substantially decrease Cu and Cr metal toxicity.

***Index Terms* - Natural dyes, Walnut husk, Pomegranate rind, Heavy metals, Biosorbent, Wastewater Remediation.**

I. INTRODUCTION

Dyeing fabrics, wood, leather, and other natural commodities with plant and animal colorants is gaining prominence. India persists as a major manufacturer of most naturally dyed textiles (Sastri, B. N. 1949). In the modern era, where sustainability is a concern, the notion of "eco-friendly" has been gaining traction. For a variety of reasons, including a preference for naturalness, environmental friendliness, reduced toxicity, and other factors, people favor organically colored textiles (Shahid, M, Islam, S, Mohammad, F. 2013).

With the rapid advancement of instrumental technology, researchers' interest in the exploration of natural color-producing substances has intensified. Moreover, they were prompted by increasing environmental consciousness to revive natural colorants extracted from natural sources such as plants (stems, bark, leaves, roots, and flowers), animals, and minerals (Samanta, A. K., Agarwal, P. 2009).

Natural dyes tend to be more beneficial to the environment than synthetic dyes. Nearly, all natural dyes are devoid of carcinogenic azo chemicals (Yusuf. M. et al., 2015). A good deal of natural dyes is known as antioxidants (Rather, L. J. et al., 2017). Every natural dye source produces an incredible range of hues. There are no health risks, and they may occasionally serve as health care (Wainwright, M., 2008). Their preparation involves nearly no or just modest chemical reactions (Vankar, Padma S. 2012). There are no disposal issues. They are simplistic and in sync with nature.

But there are certain drawbacks to the attributes of natural colors. They do have issues with color fastness and reproducibility. So, the dyeing industries use mordants with natural dyes to make their affinity to textile materials and to produce different dye shades with various levels of color fastness (Khan, M. A., Khan, M., Srivastava, P. K. & Mohammad, F., 2006). Mordants are metallic or mineral salts, which vary from slightly to deadly poisonous. Mordant, when added to the natural dye bath either it intensifies the dye or the hue is altered. They also play a large role in making the resultant shade to have prominent light and wash fastness. The dyes do not directly interact with the materials that are intended to color. The chemistry of these dyes affixing to fibres is multifaceted. Coordinate bonding is probably the most ubiquitous kind, subsequent to ionic bonding, hydrogen bonding, and hydrophobic bonding (Ali, S., Hussain, T., Nawaz, R., 2009). The presence of particular functional groups on the dye molecule at proper positions facilitates the coordination of the dye to metal ions (Shabbir et al., 2016). Stainless steel, plastic, and other non-reactive materials can be used for coloring containers. Materials like brass and iron shouldn't be utilized because they undergo their inherent mordanting (Shree Laleitha G., Srinithi M., Sasvanth S., Srinivasan M., 2020).

The two basic processes that the fabric manufacturing process in the textile industry goes through are mechanical and chemical processes. Spinning, weaving, and garmenting are examples of mechanical activities that use less water than chemical processing procedures, which include the de-sizing, scouring, bleaching, mercerizing, dyeing, printing, and finishing phases. Bleaching and dyeing produce a significant amount of effluent during the chemical process, and this effluent contains a variety of harmful pollutants, including a significant number of suspended solids (SS), organic nitrogen, traces of heavy metals, dispersants, leveling agents, salts, carriers, acids, alkalis, and different dyes (De Gisi, S., Lofrano, G., Grassi, M., Notarnicola, M., 2016). Therefore, the discharge of the aforementioned contaminants worsens the quality of the water, disperses toxicity, and adversely affects plant photosynthesis. Additionally, because of inadequate oxygen consumption and little light penetration, the aquatic ecology is greatly impacted. As a result, effluents must be properly treated before being discharged (Watkins, E., 2012).

An enormous global business, the production of textiles produces a sizable amount of wastewater. Purification of potable water and wastewater management are essential for sustaining human society's rapid development and reducing environmental pollution and health risks. Millions of people have had health issues as a result of dangerous compounds leaching into the environment and then becoming contaminated. Water resources and a developing economy are particularly at risk from textile industry wastewater pollution. Because of their complicated chemical makeup, high density heavy metals, which are non-biodegradable and more difficult to clean up (Velusamy, S., Roy, A., Sundaram, S., Kumar Mallick, T., 2021).

Heavy metal traces on textiles, heavy metal contamination in effluent, pH of the aqueous extract of the dyed textiles, pH of the effluent, product behavior in use (fastness to washing, perspiration, and rubbing both dry and wet), and development of an easy and affordable procedure to eliminate the heavy metal toxicity obtained are thus the important eco-parameters to be tested in relation to natural dyed textiles (Gautam, P. K., Gautam, R., Banerjee, S., Chattopadhyaya, M., Pandey, J. 2016).

Comparison of dye effluent discharge from various industries. **Water consumption in wet textile processing.**

Figure 1. Dye effluent discharge and water consumption in various industries

Natural dye application processes have been honed by artisans via trial and error, with no consideration for environmental concerns. Consequently, it is expected that during dyeing with natural dyes, a significant amount of the mordant might stay in the dye bath and exacerbate effluent constraints. The above-mentioned facts about natural dyes necessitates a careful examination of the environmental friendliness for future sustainability. To lessen the impact of heavy metals, a variety of enhanced procedures including chemical precipitation, adsorption, membrane separation, etc. have been developed. But among these, adsorption is the most effective and practical method (Bailey, S.E., Olin, T.J., Bricka, R.M., Adrian, D.D., 1999).

Adsorption techniques are crucial to eliminate specific kinds of pollutants from water, most notably those that are not easily biodegradable. One of the problematic groups is dyes. For the sake of the removal of dyes from wastewater, a combination of biological treatment and adsorption on activated carbon is becoming more popular. Despite the fact that commercial activated carbon is a preferred sorbent for color removal, its wide acceptance is not feasible precisely because of its high cost (More, S., Bishnoi, N.R., 2002). Low-cost adsorbent elements, including cereal straws, bagasse, the pith from chitosan trees, bidi leaves, walnut shells, and others (Geetha, K.S., 2013), have been successfully implemented to eradicate metal toxicity.

Hence, after reviewing of literature, this study was carried out with the following aims in mind:
Selection of a natural resource for natural dye extraction; evaluation of the fastness qualities of the extracted colorant on woolen cloth; if necessary, employ an appropriate mordant ($CuSO_4$, $FeSO_4$, $K_2Cr_2O_7$ or $Al_2(SO_4)_3$); estimation of metal toxicity; elimination of toxins by the application of an inexpensive natural substance like *Azadirachta indica* (Neem) and *Ocimum tenuiflorum* (Tulsi).

The current research emphasizes the extraction of natural dyes from walnut (*Juglans regia L.*) husk and pomegranate (*Punica granatum L.*) rind. Additionally, the change in colorimetric and fastness properties of wool fibres induced by the intervention of copper sulphate & potassium dichromate as mordants creating a variety of opulent colors for wool was studied. Furthermore, the metal toxicity in wastewater effluent was assessed and its eradication employing a low-cost natural material was also carried out using AAS technique.

II. RESEARCH METHODOLOGY

This component entails the extraction of natural dyes from the husk of walnut (*Juglans regia L.*) and rind of pomegranate (*Punica granatum L.*), their application, and evaluation of washing and light fastness properties, together with a mitigation of heavy metal toxicity employing natural and affordable materials.

Technical Information of Walnut (*Juglans regia L.*) and Pomegranate (*Punica granatum L.*):

- Local name → Akharot
- Botanical name → *Juglans regia*
- Part used → Husk
- Chemical constituent → Juglone
- Chemical formula → $C_{10}H_6O_3$
- Colour → Dark brown

WALNUT

- Local name → Anaar
- Botanical Name → *Punica granatum*
- Part used → Rind
- Chemical constituent → Granatonine and Tannin
- Chemical formula → $C_{21}H_8O_{12}$
- Colour → Green - yellow

POMEGRANATE

(1) Acquiring natural colorant sources:
The walnut (*Juglans regia L.*) and pomegranate (*Punica granatum L.*) were purchased from a nearby market.

(2) Colorant extraction from source:

Flow chart for extraction of colorant from Walnut (*Juglans regia L.*) and Pomegranate (*Punica granatum L.*)

Collecting Walnut for extraction
↓
Remove the nutmeat
↓
Separate the walnut husk
↓
Grinding in milcent
↓
Powder form
↓
Powder (50 gm) + Water (1000 ml)
↓
Swell overnight at room temperature
↓
Boiled swollen powder for 5 hours
↓
Filtered by filter paper
↓
Dried the filtrate at 60°C in shade
↓
Collected the colourant
↓
Weighed

Walnut Dye yield

Raw material = 50gm

Yield = 2.50gm

Yield % = (2.50/50) x 100

= 5%

Collecting Pomegranate for extraction
↓
Separate the Pomegranate rind
↓
Grinding in milcent
↓
Powder form
↓
Powder (50 gm) + Water (1000 ml)
↓
Swell overnight at room temperature
↓
Boiled swollen powder for 5 hours
↓
Filtered by filter paper
↓
Dried the filtrate at 60°C in shade
↓
Collected the colourant
↓
Weighed

Pomegranate Dye yield

Raw material = 50gm

Yield = 3.50gm

Yield % = (3.50/50) X 100

= 7%

Figure 2. Shade of sample without mordant

(3) Colorant application on woolen cloth piece

Materials

Cloth: Woollen cloth piece was taken for this study**.** The woolen fabric was washed well (Nonionic detergent (0.5%), 50ºC/30min) and dried at ambient condition for dyeing with the sample size 15 X 15cm.

Chemicals used: Mordant [$CuSO_4$, $FeSO_4$, $K_2Cr_2O_7$, $Al_2(SO_4)_3$], CH_3COOH. All other chemicals were LR grade.

The mild scoured fabric was dyed with colorant under suitable conditions (95°C, 1:50 MLR, pH 4-5, CH_3COOH-5%) and mordanting in proper concentration. The three well-known dyeing techniques are described via the flow charts below.

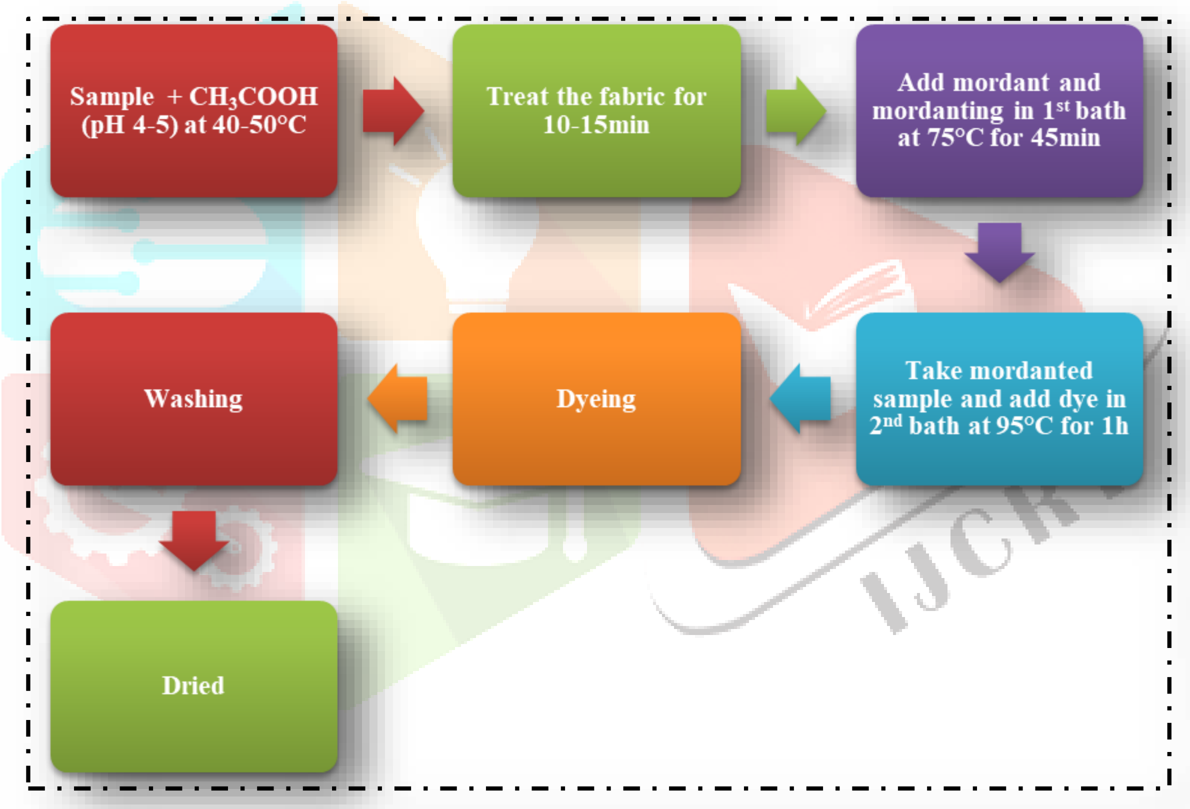

Figure 3. Pre-mordanting technique

Figure 4. Simultaneous mordanting and dyeing technique

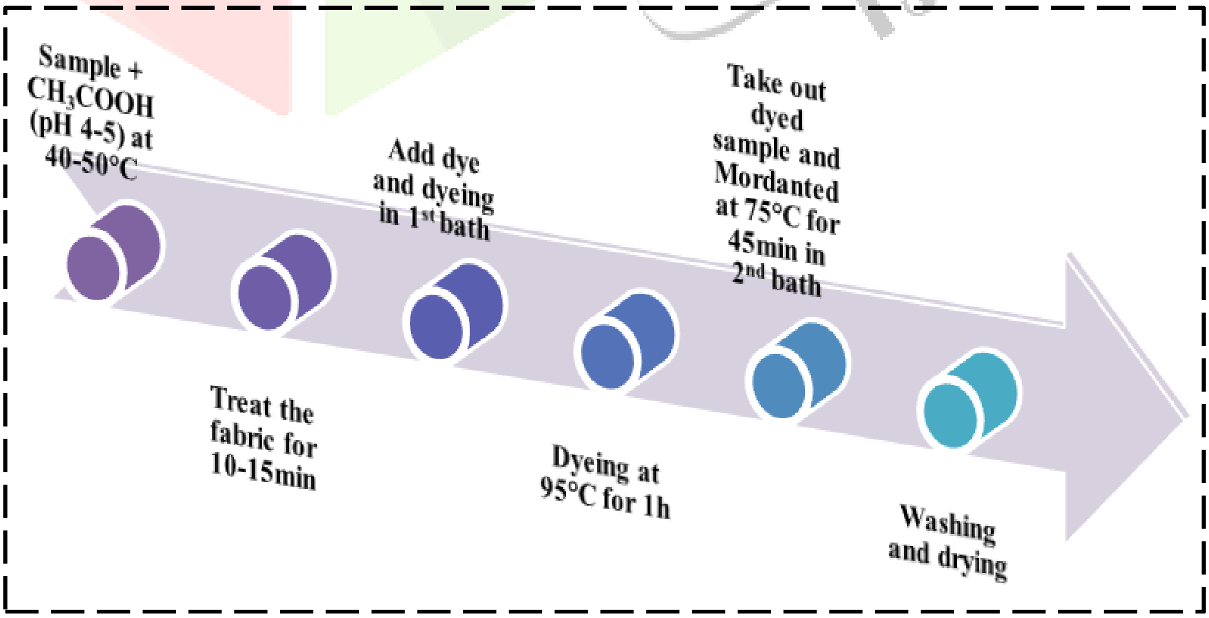

Figure 5. Post-mordanting technique

The infrared (IR) spectra were computed utilizing a KBr pellet and a Bruker FTIR spectrometer ALPHA II. The wavenumbers (ν_{max}) of the detected infrared signals are stated in cm^{-1}.

(4) Color fastness properties assessment

Colorimetric values (K/S) of dyed woolen cloth (at 410 nm λ_{max})

The K/S, L*, C* and H* values are ascertained via a SYSTRONICS colorimeter 115. Under the presence and absence of four distinct mordants, the colorimetric value of woolen fabric dyed with a colorant derived from walnut (*Juglans regia L.*) (Table 1) and pomegranate (*Punica granatum L.*) (Table 2) is measured.

Evaluation of Washing Fastness

The washing fastness will be assessed by means of the Grey Scale. The grey scale is a geometric scale, and its graduation is calculated in NBC (National Bureau of Standards) units, which correspond to the smallest difference in commercial significant depth. The International Organization of Standards has acknowledged light and wash fastness ratings of 3 and higher as professionally essential (Nasirizadeh, N., Dehghanizadeh, H., Yazdanshenas, M.E., Moghadam, M.R., Karimi, A., 2012). Formulated a detergent solution (3 g of nonionic detergent in 1000 ml of water), placed 100 ml of the detergent solution in each water bath, and dipped the cloth in it for 30 minutes at 45°C before washing and drying the samples. The washing fastness was estimated by the dullness of the colored fabric (Table 3 and Table 4).

Analysis of Light Fastness

The colorant's propensity to endure harsh circumstances such as light and wash solution on textile fibre is vital. The light fastness is determined using BLUE WOOL STANDARDS. Patterns ranging from 1 to 8 are the blue wool standards (Oda, H., 2010). Dyed samples were laid out on a piece of cardboard. Half of the samples endured exposure to sunlight for 8 hours while being draped with a black sheet. The samples were subsequently removed, and the light fastness was evaluated based on the degree of fading (Table 5).

(5) Investigation of heavy metal toxicity in deployed samples and removal of the toxicity employing natural resources (dry leaves of Azadirachta indica and Ocimum tenuiflorum).

Atomic Absorption Spectroscopy is used to estimate metal toxicity in water wastes. Following the dyeing process, waste water from the dye bath or sewage was collected and the metal content (Cu & Cr in mg/l) was calculated. For that, waste water was drained from the sewer and 250ml of effluent was collected in four separate beakers. The effluent was infused with distinct quantities (2 & 4gm) of dried leaves of *Azadirachta indica* and *Ocimum tenuiflorum* in each beaker, and the pH was adjusted at 5. The solution was simmered for 150 min at 60-70°C. The solution was filtered, and AAS analysis was performed.

III. RESULTS AND DISCUSSION

The relationship among woolen yarn samples, mordants, and dye molecules was investigated in this study evaluating augmented color strength values (K/S) in the presence and absence of mordant and after dyeing processes. Likewise, FTIR spectral analysis was conducted to recognize the chromophoric groups encountered in dye molecules that have been speculated to serve as the elementary contributors to strengthened chemical liaisons. The Fourier transform infrared (FTIR) spectra of *J. regia* and *P. granatum* extracted dyes manifest three prominent bands at 3224-3190, 1658-1656 and 1011-1010 cm^{-1}, which symbolize the frequency range of OH stretching and C=O stretching and C-O stretching, respectively (Fig. 6 and 7). It can be inferred that NH stretching bands are overlapped by absorption due to OH stretching.

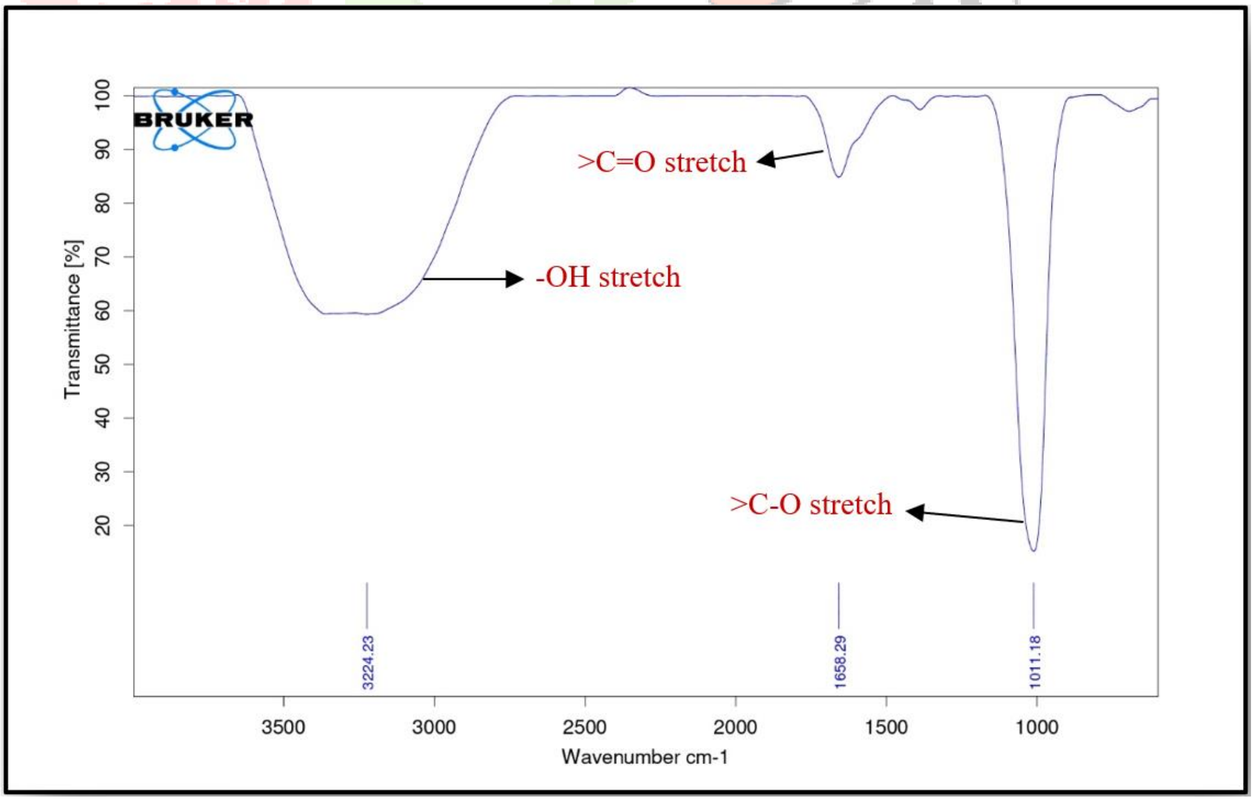

Figure 6. FTIR spectra of walnut (*Juglans regia L.*) dye

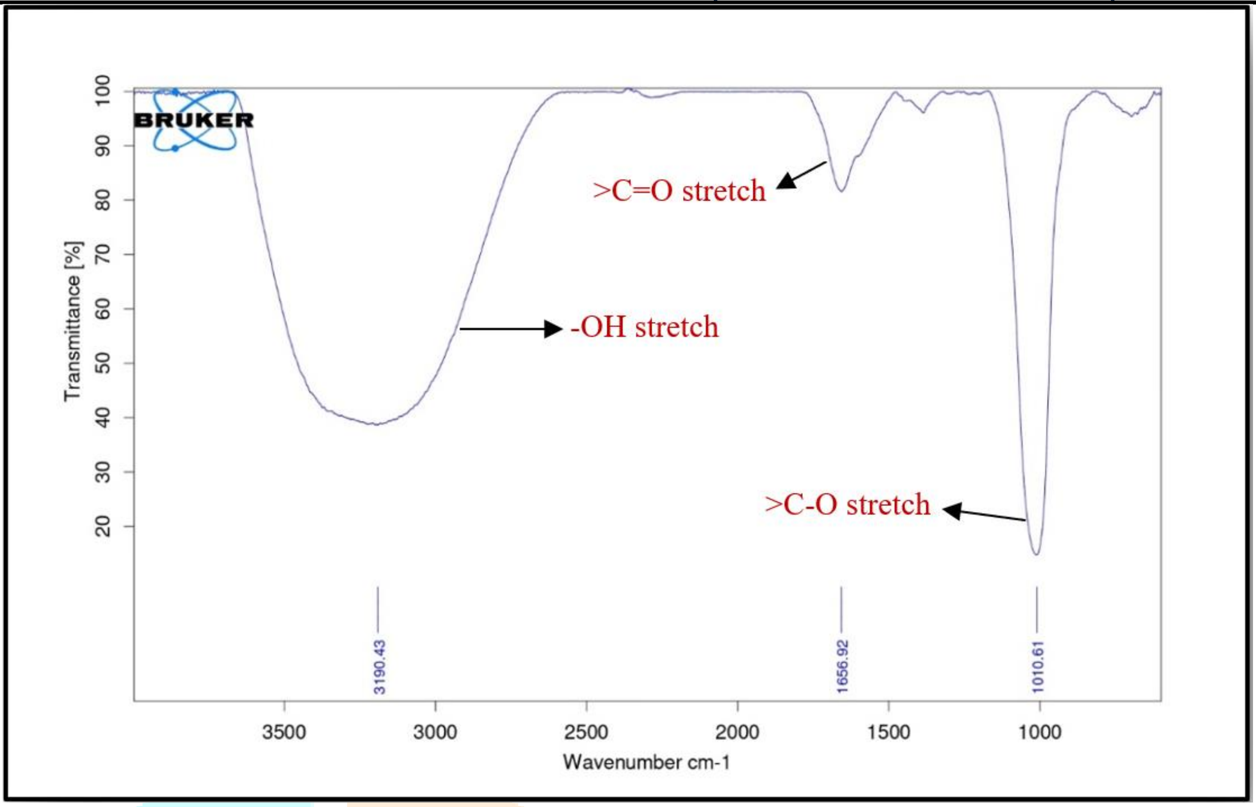

Figure 7. FTIR spectra of pomegranate (*Punica granatum L.*) dye

The colorimetric value of woolen fabric dyed with colorant extracted from walnut (*Juglans regia L.*) and pomegranate (*Punica granatum L.*) in the inclusion and exclusion of four distinct mordants via three mordanting techniques is depicted in Table 1 and 2. Mordanting inevitably has an impact on the fabric's penultimate hue due to the fact that it strengthens the interaction between woolen yarn functional groups (amine functionality) and dye functional groups (hydroxyl and carbonyl groups), resulting in increased dye exhaustion values, and this can be precisely associated with enhanced color strength indicators for dyed woolen yarn samples. Without mordanting, the colorants produced were creamy yellow and light brown, respectively, however after mordanting; the final color varies from grey to peach for both scenarios (relying on the sort of mordant) with walnut yielding a brownish tinge (Fig. 10) and pomegranate gives a yellowish tinge (Fig. 11). The colorimetric data indicates that brightness minimizes after mordanting as color changes and depth increases. Among mordants, 20% walnut dye + 5% $FeSO_4$ affords the strongest color depth in the post mordanting method. (Entry 16, Table 1), that can be pinned down to the strong coordinate complex formation tendency of ferrous sulphate within the fibre, whereas 20% pomegranate dye + 5% $CuSO_4$ offers the most prominent color depth in the other case (Entry 15, Table 2). It is also evident that the post mordanting method turns out to be the best in both instances. Figure 12 depicts an envisioned schematic illustration for enhanced interactions of dye and woolen yarn during the mordanting processes.

Table 1. Colorimetric values of woolen fabric dyed with colorant extracted from Walnut with or without mordanting (at λ_{max} 410 nm)

S. No.	Method	Mordant	L*	C*	H*	K/S
1	Undyed Sample	-	84.32	8.14	87.31	0.191
2	Only dyeing	-	74.41	12.00	75.07	0.553
3	Only Mordanting	$CuSO_4$	79.82	5.97	86.21	0.439
4		$FeSO_4$	80.69	9.51	60.82	0.149
5		$K_2Cr_2O_7$	68.52	20.67	75.23	1.941
6		$Al_2(SO_4)_3$	84.20	6.98	52.82	0.182
7	Pre-mordanting + Dyeing	$CuSO_4$	64.71	12.69	79.11	1.183
8		$FeSO_4$	57.81	1.46	82.31	1.049
9		$K_2Cr_2O_7$	66.04	11.67	80.31	0.682
10		$Al_2(SO_4)_3$	77.15	15.99	71.45	0.610
11	Simultaneous mordanting and dyeing	$CuSO_4$	63.64	12.17	73.89	1.416
12		$FeSO_4$	58.13	3.60	93.18	1.890
13		$K_2Cr_2O_7$	62.14	21.37	58.40	1.933
14		$Al_2(SO_4)_3$	73.38	18.89	78.06	0.555
15	Dyeing +	$CuSO_4$	58.05	18.94	72.50	1.498

16	Post-Mordant	$FeSO_4$	57.91	18.15	71.22	3.447
17		$K_2Cr_2O_7$	84.15	15.72	86.65	2.649
18		$Al_2(SO_4)_3$	68.22	15.99	79.78	1.731

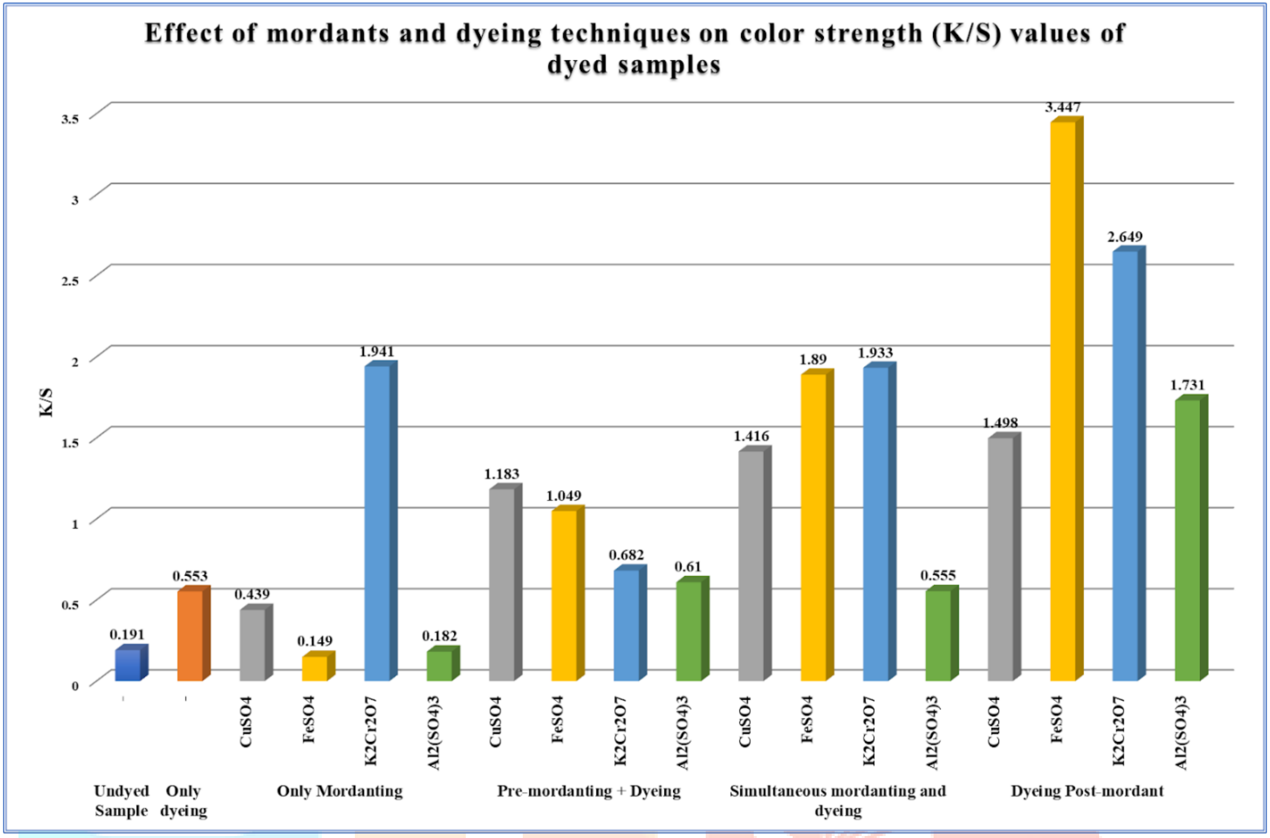

Figure 8. Effect of mordants and dyeing techniques on color strength (K/S) values of dyed samples of walnut extract

Table 2. Colorimetric values of woolen fabric dyed with colorant extracted from Pomegranate with or without mordanting (at λ_{max} 410 nm)

S. No.	Method	Mordant	L*	C*	H*	K/S
1	Undyed Sample	-	81.50	8.91	10.06	0.134
2	Only dyeing	-	70.42	17.73	82.73	0.692
3	Only Mordanting	$CuSO_4$	72.33	13.83	79.05	0.576
4		$FeSO_4$	84.96	8.29	94.66	0.328
5		$K_2Cr_2O_7$	73.40	9.27	124.23	0.491
6		$Al_2(SO_4)_3$	72.35	5.28	100.71	0.510
7	Pre-mordanting + Dyeing	$CuSO_4$	52.89	4.26	78.30	0.755
8		$FeSO_4$	68.35	21.32	76.88	0.674
9		$K_2Cr_2O_7$	60.18	15.05	77.61	0.799
10		$Al_2(SO_4)_3$	66.31	16.85	83.33	0.778
11	Simultaneous mordanting and dyeing	$CuSO_4$	54.11	1.92	105.59	0.746
12		$FeSO_4$	70.63	17.80	83.94	0.672
13		$K_2Cr_2O_7$	57.31	12.01	77.25	0.833
14		$Al_2(SO_4)_3$	65.81	14.08	83.03	0.755
15	Dyeing + Post - mordanting	$CuSO_4$	52.12	3.84	98.43	0.846
16		$FeSO_4$	68.80	20.49	85.64	0.820
17		$K_2Cr_2O_7$	59.66	14.24	81.78	0.795
18		$Al_2(SO_4)_3$	66.47	18.56	81.93	0.819

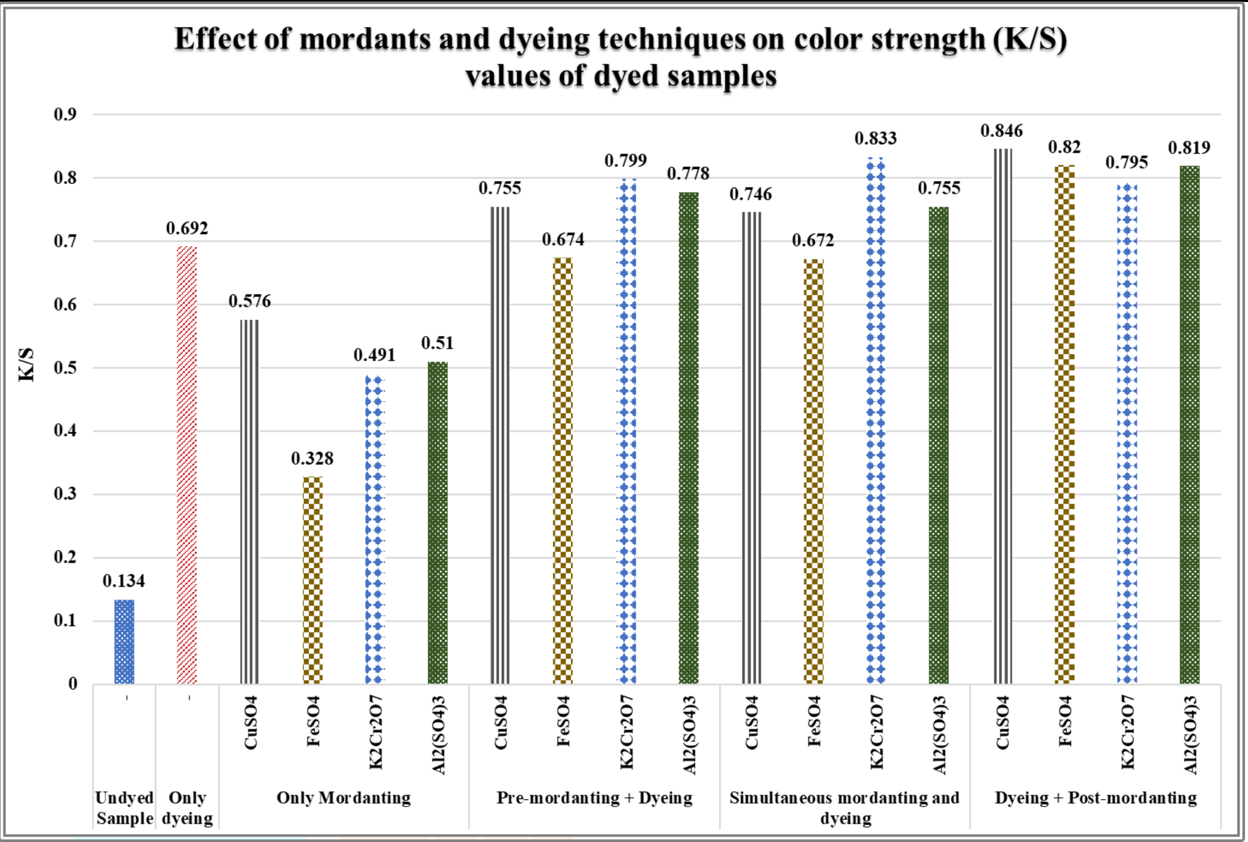

Figure 9. Effect of mordants and dyeing techniques on color strength (K/S) values of dyed samples of pomegranate extract

Figure 10. Shade with 20% walnut dye + 5% $FeSO_4.7H_2O$

Figure 11. Shade with 20% pomegranate dye + 5% $CuSO_4.5H_2O$

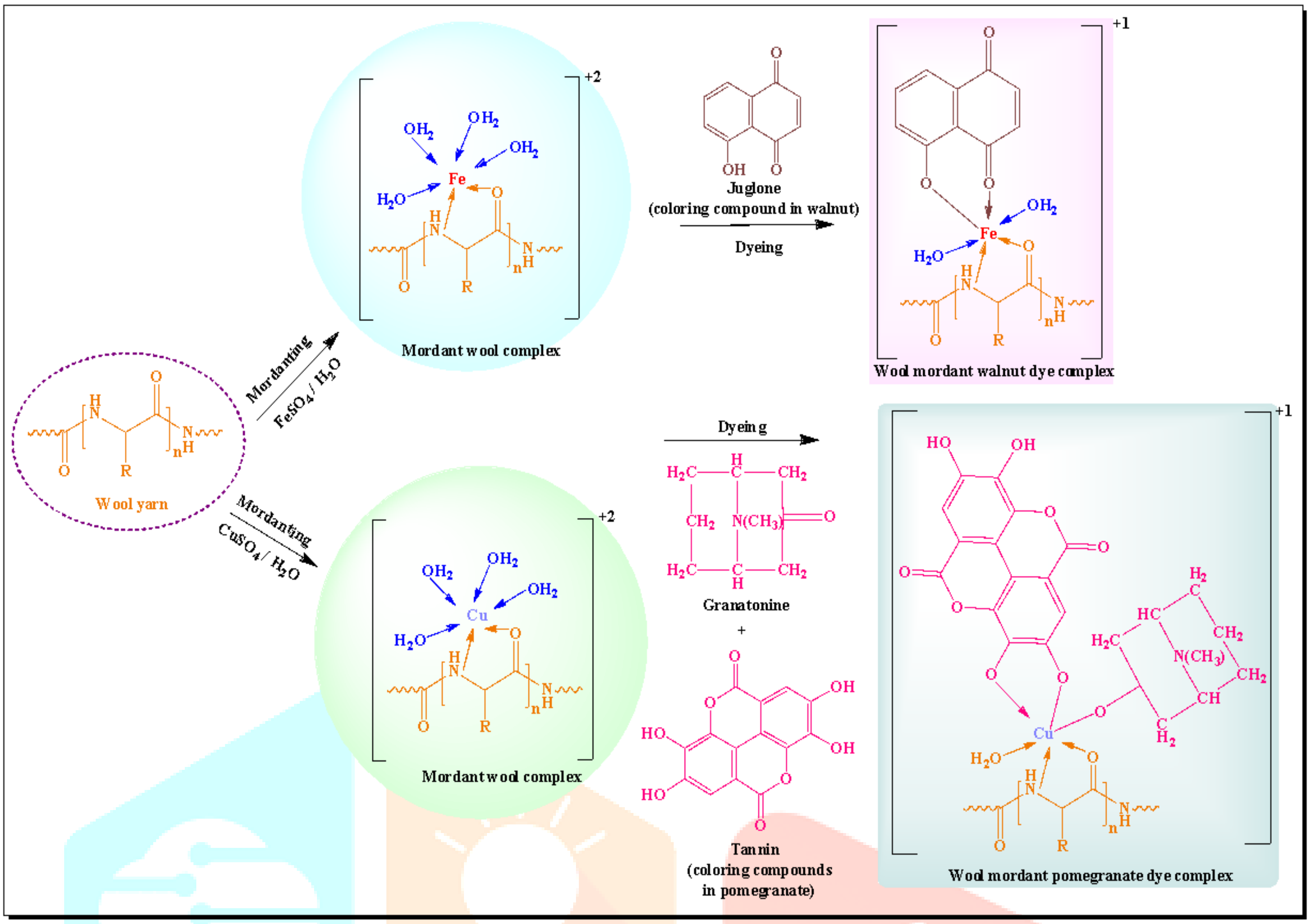

Figure 12. Schematic representation of wool-mordant-dye interaction

Colorant from walnut (*Juglans regia L.*) exhibits a surge in fastness characteristics after mordanting owing to the formation of metal-dye complexes. Tables 4 and 5 show the outcomes of screening the dyed samples per Indian standard techniques. The fixation of mordant on woolen fabric without natural dye is low, thus their fastness properties are good. Based on the results, all samples acquired good to exceptional light fastness ratings on the blue scale through the color fastness tests. There is not a substantial variance in the washing fastness of dyed samples across mordants and mordanting technique, albeit the $K_2Cr_2O_7$ mordanted samples are weaker in light fastness property than those with other mordants.
The washing fastness of woolen fabric dyed with pomegranate colorant is akin to that of walnut (*Juglans regia L.*) colorant. Comparing mordants and methods of mordanting, there are no discernible differences in the washing fastness of dyed samples. Progressively this implies that both the dyes meet the criteria for commercial applications.

Table 3. Fastness properties of woolen fabric dyed with walnut with or without mordanting.

S. No.	Mordanting Method	Mordant used	Washing fastness		Light fastness
			Change in shade	Change in stain	
1	Only dyed	-	5	5	6-7
2	Only Mordant	$CuSO_4$	4	5	5-6
3		$FeSO_4$	4	5	5
4		$K_2Cr_2O_7$	3	4	4-5
5		$Al_2(SO_4)_3$	4	5	5-6
6	Pre-mordanting	$CuSO_4$	5	5	6-7
7		$FeSO_4$	5	5	6
8		$K_2Cr_2O_7$	5	5	5-6
9		$Al_2(SO_4)_3$	4-5	4-5	6-7
10	Simultaneous dyeing and mordanting	$CuSO_4$	5	5	6-7
11		$FeSO_4$	5	5	6
12		$K_2Cr_2O_7$	4-5	4-5	5
13		$Al_2(SO_4)_3$	5	5	6-7
14	Post-Mordanting	$CuSO_4$	5	5	6-7
15		$FeSO_4$	5	5	6-7

16		$K_2Cr_2O_7$	4-5	4-5	5
17		$Al_2(SO_4)_3$	4-5	5	6-7

Table 4. Fastness properties of woolen fabric dyed with pomegranate with or without mordanting.

S. No.	Mordanting Method	Mordant used	Washing fastness		Light fastness
			Change in shade	Change in stain	
1	Only dyed	-	5	5	6-7
2	Only Mordant	$CuSO_4$	4	5	5-6
3		$FeSO_4$	4	5	5
4		$Kr_2Cr_2O_7$	3	4	4
5		$Al_2(SO_4)_3$	4	5	5-6
6	Pre-mordanting	$CuSO_4$	5	5	7
7		$FeSO_4$	5	5	6
8		$Kr_2Cr_2O_7$	4	5	5
9		$Al_2(SO_4)_3$	4	4-5	6
10	Simultaneous dyeing and mordanting	$CuSO_4$	4	5	6-7
11		$FeSO_4$	5	5	6
12		$Kr_2Cr_2O_7$	4-5	4-5	5
13		$Al_2(SO_4)_3$	4-5	5	7
14	Post-Mordanting	$CuSO_4$	4	5	6-7
15		$FeSO_4$	4	4	6
16		$Kr_2Cr_2O_7$	4-5	4-5	5
17		$Al_2(SO_4)_3$	4-5	5	6-7

The final endeavor was to scrutinize heavy metal toxicity in deployed samples and then eliminate the toxicity via low-cost natural resources such as leaves of *Azadirachta indica* and *Ocimum tenuiflorum*. The former was employed to remove Cr, while the latter was utilized to remove Cu in this reduction procedure. The water effluent was submitted to the Rajasthan Pollution Control Board for AAS analysis of heavy metals after using the mordant and completing the dyeing process from walnut (*Juglans regia L.*) and pomegranate (*Punica granatum L.*) dye on woolen cloth piece, and the total Cr as well as Cu present per litre sample of effluent are depicted in tables 5 and 6. It may be inferred that the Cu and Cr concentrations of the water effluent from walnut dye exceed those of pomegranate dye (Entry 1 and 2 of Table 5 and 6).
After reviewing the Rajasthan Pollution Control Board's insights, *Azadirachta indica* and *Ocimum tenuiflorum* leaves were introduced to the water effluent to eradicate metal toxicity. Tables 5 and 6 summarize the AAS observations reported after employing plant leaves.

Table 5. AAS analysis of walnut effluent before and after application of removal technique.

S. No.	Removal technique	Sample (Walnut)	Parameter	Results (mg/l)
1.	Not applied	Walnut + $K_2Cr_2O_7$	Total Chromium as Cr mg/l	1854.5
2.		Walnut + $CuSO_4$	Total Copper as Cu mg/l	498.7
3.	Applied	Walnut + $K_2Cr_2O_7$ + 2gm/l Tulsi	Total Chromium as Cr mg/l	383.70
4.		Walnut + $K_2Cr_2O_7$ + 4gm/l Tulsi	Total Chromium as Cr mg/l	276.15

5.		Walnut + $CuSO_4$ + 2gm/l Neem	Total Copper as Cu mg/l	60.14
6.		Walnut + $CuSO_4$ + 4gm/l Neem	Total Copper as Cu mg/l	16.74

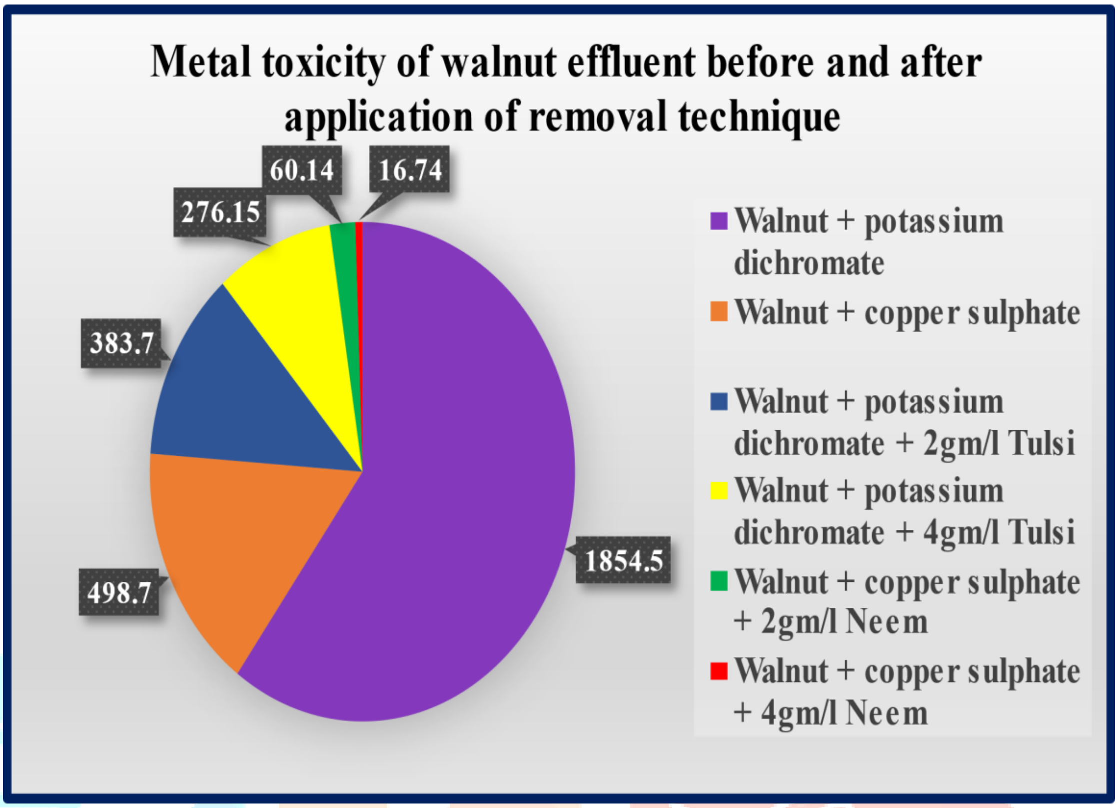

Figure 13. Metal toxicity of walnut effluent before and after application of removal technique

Table 6. AAS analysis of pomegranate effluent before and after application of removal technique

S. No.	Removal technique	Sample (Pomegranate)	Parameter	Results (mg/l)
1.	Not applied	Pomegranate + $K_2Cr_2O_7$	Total Chromium as Cr mg/l	974.1
2.		Pomegranate + $CuSO_4$	Total Copper as Cu mg/l	393.8
3.	Applied	Pomegranate + $K_2Cr_2O_7$ + 2gm/l Tulsi	Total Chromium as Cr mg/l	336.9
4.		Pomegranate + $K_2Cr_2O_7$ + 4gm/l Tulsi	Total Chromium as Cr mg/l	327.9
5.		Pomegranate + $CuSO_4$ + 2gm/l Neem	Total Copper as Cu mg/l	49.17
6.		Pomegranate + $CuSO_4$ + 4gm/l Neem	Total Copper as Cu mg/l	20.55

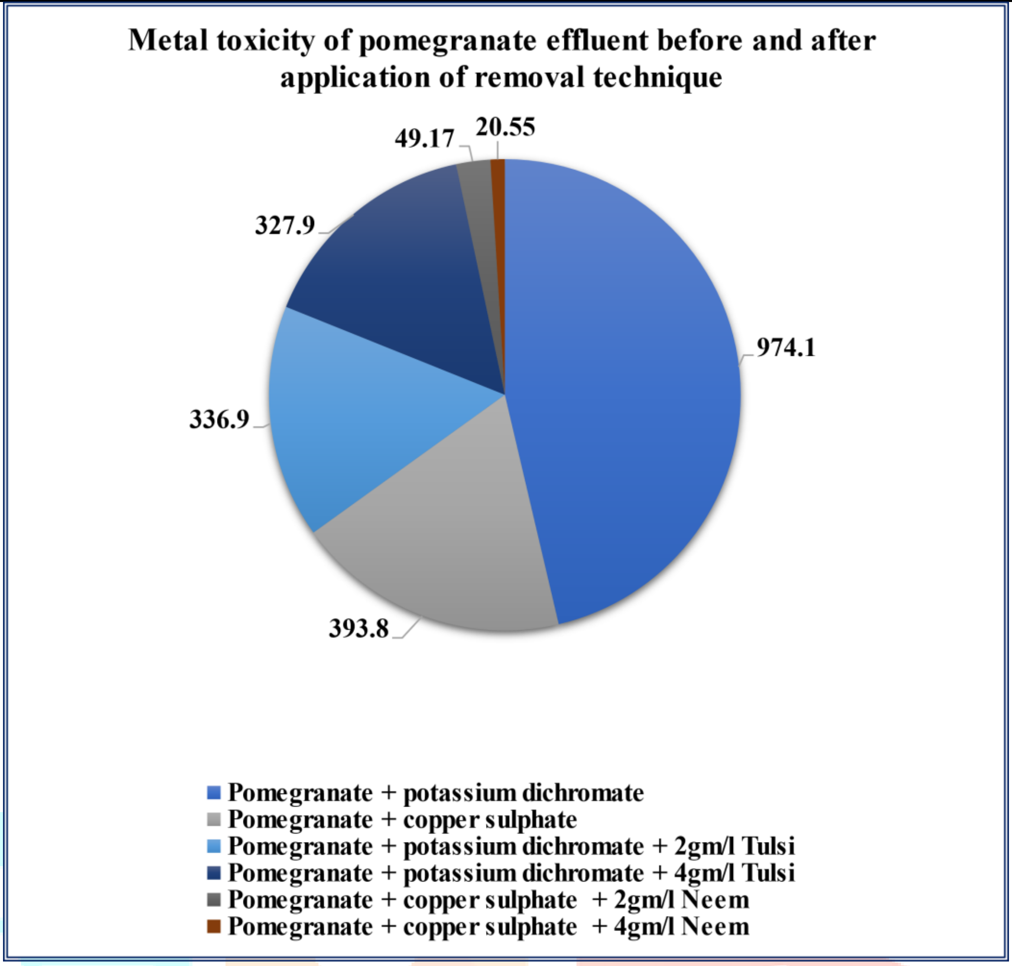

Figure 14. Metal toxicity of pomegranate effluent before and after application of removal technique

These findings demonstrate that treating water effluent with *Azadirachta indica* and *Ocimum tenuiflorum* leaves negates metal toxicity. Furthermore, by elevating the leaf content, the metal toxicity content is drastically lessened. As a result, this strategy may become widely accepted and implemented across industries that seek to reduce expenses and boost profitability.

IV. CONCLUSION

Woolen fabric was dyed with a natural dyeing agent extracted from walnut (*Juglans regia L.*) and pomegranate (*Punica granatum L.*) with the intention to discover natural hues in conjunction using several metallic salt mordants. Novel and stylish hues of light and bright brown emerged in walnut (*Juglans regia L.*) mordanted dyed samples, as well as creamy yellow tones in pomegranate (*Punica granatum L.*) dyed samples. All of the colored woolen yarn samples had light fastness scores ranging from good to extraordinary. The wash fastness property was found to range from fair to outstanding. Additionally, to eliminate heavy metal toxicity in dyed water effluent, leaves of *Azadirachta indica* and *Ocimum tenuiflorum* were discovered to be a good candidate for Cr and Cu biosorption respectively. Furthermore, metal toxicity can be substantially reduced conveniently by increasing the number of leaves per litre of water effluent. Considering the outcomes of colorimetric analysis, fastness attributes, and heavy metal toxicity elimination employing low-cost adsorbents, it is conceivable to speculate that dye derived from walnut (*Juglans regia L.*) and pomegranate (*Punica granatum L.*) possesses an optimistic outlook inside the textile coloration industry.

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