Indian Journal of Fibre and Textile Engineering (IJFTE)
ISSN: 2582-936X (Online), Volume-3 Issue-2, November 2023

# Protecting Hand-Knotted Carpets with Microbial Resistance

**Raj Yadav, Richa Khulbe, Ashok Athalye**

***Abstract:*** ***The carpet is a textile material known for its aesthetic appeal and is widely used for enhancing home and workplace décor. The hand-knotted carpets made from natural fibres like cotton tend to allow microbial growth when exposed to hot and humid conditions. This study involves the application of anti-microbial finishing chemicals developed from natural oils like Neem, Basil, and Aloe vera. Nano-emulsion of essential oil was prepared with polyoxyethylene sorbitan monooleate as a surfactant using a high-speed Homogenizer at 15K rpm for 30 minutes. These essential oils can repel insects like house flies and prevent the growth of microbes which cause human health-related issues like skin itching, irritation, sneezing and allergy. Varying concentrations of emulsion oil 1% and 5% were used to prepare nano-emulsion formulation, and the particle size and thermal stability were evaluated. FTIR analysis of the emulsion was done to check the presence of functional groups. The spraying technique was used for the application of neem oil emulsion on the carpet and dried. The finished carpet was tested for the anti-microbial performance effect and found to provide adequate microbial protection.***

***Keywords:*** ***Antimicrobial Finishing, Essential Oils, Hand-Knotted Carpets, Nano-Emulsion Formulation, Valorisation of Carpets***

## I. INTRODUCTION

The hand-knotted carpet industry in India has been a part of the global value chain and India alone is responsible for 40% of global exports of the carpets since the British ruled India. The Bhadohi-Mirzapur area, frequently called the carpet belt of India, produces most hand-knotted carpets exported to other countries [1]. Historically, carpets were invented as floor coverings to protect people from adverse climates. With growing civilisation and cultural evolution, the artistic and aesthetic value of carpets as home furnishing components and traditional ceremonial materials increased [2],[14].

**Manuscript received on 09 September 2023 | Revised Manuscript received on 20 September 2023 | Manuscript Accepted on 15 November 2023 | Manuscript published on 30 November 2023.**

* Correspondence Author (s)
**Mr. Raj Yadav,** Department of Fibres and Textile Processing Technology, Institute of Chemical Technology, Mumbai (Maharashtra), India. E-mail: sumanrjyadav1420@gmail.com
**Ms. Richa Khulbe,** Department of Fibres and Textile Processing Technology, Institute of Chemical Technology, Mumbai (Maharashtra), India. E-mail: tch22rn.khulbe@pg.ictmumbai.edu.in
**Dr. Ashok Athalye*,** Department of Fibres and Textile Processing Technology, Institute of Chemical Technology, Mumbai (Maharashtra), India. E-mail: ar.athalye@ictmumbai.edu.in, ORCID ID: 0000-0002-2480-907X



The carpet weavings have fully or partially displayed traditional decorations and motifs. India has an extensive tradition of weaving hand-knotted carpets, which most likely dates to its initial trade with the Middle East and Europe. Over the centuries, the unique Indian hand-knotted carpets spread around the globe and are fondly termed antique carpets. As urbanisation and living standards rise, so does the global market for carpets. With over 15 lakh carpet weavers employed and 3 lakh looms, India has a significant and diverse base for carpet production. The distinctive and specialised hand-knotted carpets are widely exported worldwide, contributing to the growth of the Indian economy and the textile sector by generating foreign exchange [3],[15]. However, they have a long history of being used as a medium to promote the growth of microorganisms, including bacteria and fungi. Microorganisms are found everywhere in the environment and close to the skin of humans as skin flora. They may reproduce swiftly in basic development circumstances like moisture, nutrients, and temperature. Under humid conditions, natural protein and carbohydrate fibres such as cotton, wool, etc. which are used in the carpet, serve as energy as well as nutrition sources for microorganisms. Therefore, microbial attacks easily break down these fibres [4].

The growing popularity of carpeting in home textiles, hospitals and other institutions emphasises the demand for carpeting to possess a special quality that inhibits the growth of bacteria and fungi, known as antimicrobial efficiency.

Current research focuses on modifying the carpet surface using different concentrations of Neem, Basil and Aloe vera oil emulsion [5-13]. Applying nano-emulsion on the hand-knotted carpet will introduce desirable antimicrobial and flame-retardant functionalities. No significant research has been done on preparing and applying such nano-emulsion on the hand-knotted carpet. This work hypothesized that it would help create a solution that can be easily made and used by weavers in their working area and impart desirable functionality, improving the value of carpets in export.

## II. EXPERIMENTAL WORK

Three hand-knotted carpet samples were manufactured by the local weavers of Bhadohi of quality 7/25, 8/25, 9/25 (Table 1) made of 100% wool yarn. Neem oil, Basil oil, and Aloe vera oil were procured from Matunga Ayurvedic shop no-8 LN Road, Mumbai. Tween 80 LR (Polyoxyethylene sorbitan monooleate, Polysorbate 80) was procured from DFCL, and Distilled water (DW) was taken of lab-grade quality.

| Table 1: Technical Specifications of the hand knotted carpet samples. | |
|---|---|
| Size Sample | *1.5'x1.5'* feet |
| Knot yarn count | *60s* |
| Base yarn count | 60s |
| Knotting yarn substrate | Indian fine wool |
| Base yarn substrate | Indian fine wool |
| Knots Density | 40-45,50-55,56-60 KPSI |
| Pile Height | 6-7 mm for all sample |
| GSM | 3000-3200,3200-3300,3400-3600 |
| Quality of carpet sample | 7/25,8/25/9/25 |
| Colour | Wool- milky white, cotton-white |
| Weaving Technique | Turkish knots |

### 2.1 Preparation of 1% Neem, Basil and Aloe vera oil emulsion

A 100 ml of emulsion is prepared by dissolving neem oil and surfactant in the distilled water 1ml of Neem oil was added dropwise in the mixture of 0.5 ml of Tween 80(surfactant) and 98.5 ml of distilled water and using High-speed homogenizer (Ultra-Turrax T25 digital, IKA Works Inc., China) at 15000 rpm constant stirring speed rate for 30 min. A similar method was used to prepare 1% basil and aloe vera oil emulsion.

### 2.2 Preparation of 5% Neem, Basil and Aloe vera oil emulsion

A 100 ml emulsion is prepared by dissolving neem oil and surfactant in distilled water. 5ml of Neem oil was added dropwise in the mixture of 2.5 ml of Tween 80(surfactant) and 92.5 ml of distilled water and using a High-speed homogenizer (Ultra-Turrax T25 digital, IKA Works Inc., China) at 15000 rpm constant stirring speed rate for 30 min. A similar method was used to prepare 5% basil and aloe vera oil emulsion.

### 2.3 Application of nano-emulsions on hand-knotted carpet

Three Carpet sample size was taken of dimension 10cm×10cm. The spray technique method (Fig 1) was used to apply the nano-emulsions on the sample. Three samples were sprayed with the emulsion solutions (i.e., neem oil, basil oil and aloe vera oil, each 1% concentration) and dried for 6-7 hours in the presence of optimum sunlight. A similar process was repeated for a 5% concentration of emulsion solution.

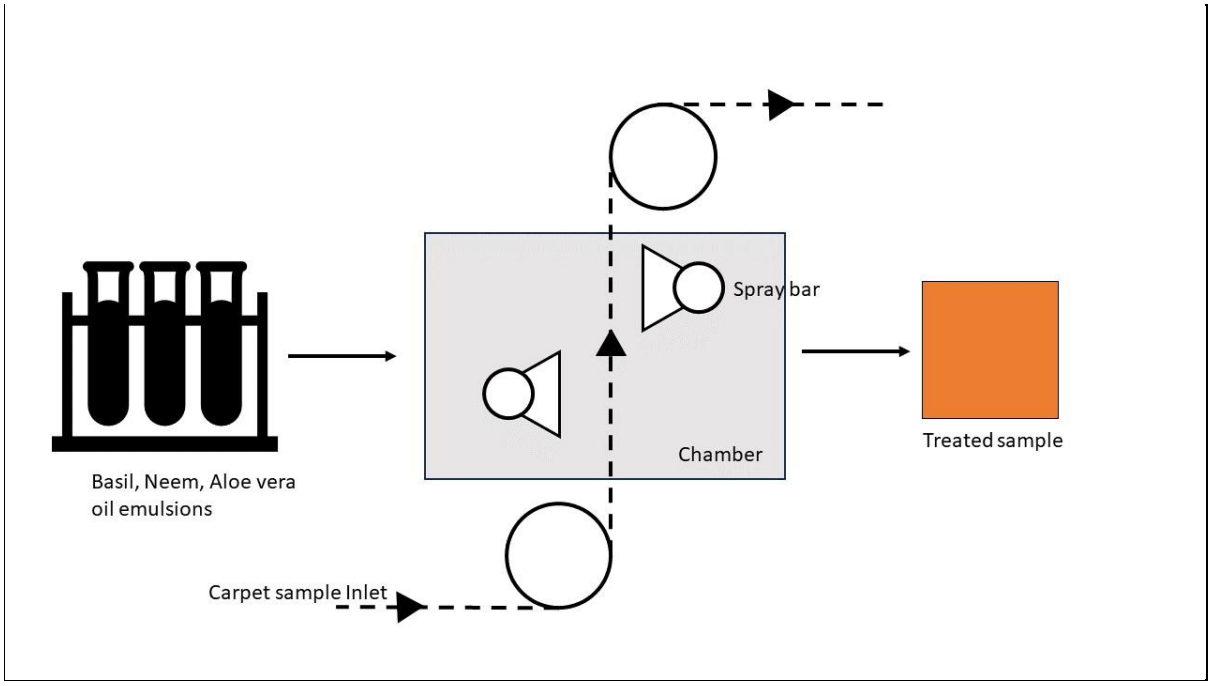


**Figure 1: Application of Emulsified Oil on the hand-knotted carpet**

## III. EVALUATION

### 3.1 Knot Density

Knot density is determined by evaluating knots per square inch (KPSI). This indicates the number of vertical knots multiplied by horizontal knots in one square inch of carpet and measured according to standard IWS/TM-283: 2000. The higher the knot density higher the apparent value of the carpet.

### 3.2 Particle Size Analysis

Determination of the particle size of the various nano-emulsion was done using a Particle Size Analyzer (SALD 7500 nano, Shimadzu, Japan).

### 3.3 Thermal stability

A thermal stability study of nano-emulsion was carried out to check the effect of temperature on emulsion. Pilot testing was done at various room temperatures varying from the range of 4 ℃ to 40℃ to stimulate the conditions of the working environment at the local weaving place. The observations were taken after 24 hours.

### 3.4 Chemical deposition

The chemistry of interfacial bonding and the shift in functional groups were analysed using Fourier Transform Infrared Spectroscopy (FTIR). A few successive scans of the IR spectra were acquired for characterization on the FTIR-8400S (Shimadzu Corporation, Japan) at a resolution of 4 cm 1. The wavenumber ranged from 600 to 4000 cm 1.

### 3.5 Flammability Test

Surface Flammability of Carpet according to standard 16 CFR 1630/1631: 1979 The flammability of the samples was evaluated by measuring the radius of ignition with the help of a circular scale.

### 3.6 Antimicrobial Activity

AATCC 100 test method was used to determine the antimicrobial efficiency of the treated carpet samples against Staphylococcus Aureus (Gram-positive) and Escherichia Coli (Gram-negative) bacteria. The bacterial strain was cultured for 24 hours using nutrient broth.

Each carpet sample (1.00 g) was cut into small pieces (1 by 1 cm) and transferred to a 250 ml Erlenmeyer flask containing 100 ml of the working bacterial dilution. All flasks were capped loosely, placed on the incubator, and shaken for 1 hr at $37^0$C and 120 rpm using an incubator shaker (New Brunswick Scientific, NJ, USA). After a series of dilutions of the bacterial solutions using the buffer solution, 1 ml of the dilution was plated in nutrient agar. The inoculated plates were incubated at $37^0$C for 24 hours and surviving cells were counted.

The antimicrobial activity was expressed in terms of % reduction of the organism after contact with the test specimen compared to the number of bacterial cells surviving after contact with the control. The percentage reduction was calculated using the following equation 1.

$$\% \text{ Reduction} = \{(B - A)/B\} * 100; \text{ ---------- Eq1.}$$

where A and B are the surviving cells (CFU/ml) for the flasks containing test samples (NMA-HTCC treated samples) and the control (blank cotton), respectively, after 1 hr contact time.

## IV. RESULTS AND DISCUSSION

### 4.1 Knot Density

The quality of the handmade carpets is determined based on the carpets' age, origin, condition, and design and the carpet with more knots is considered more valuable. Figure 2 shows the effect on the knot density of different carpets after essential oil application.

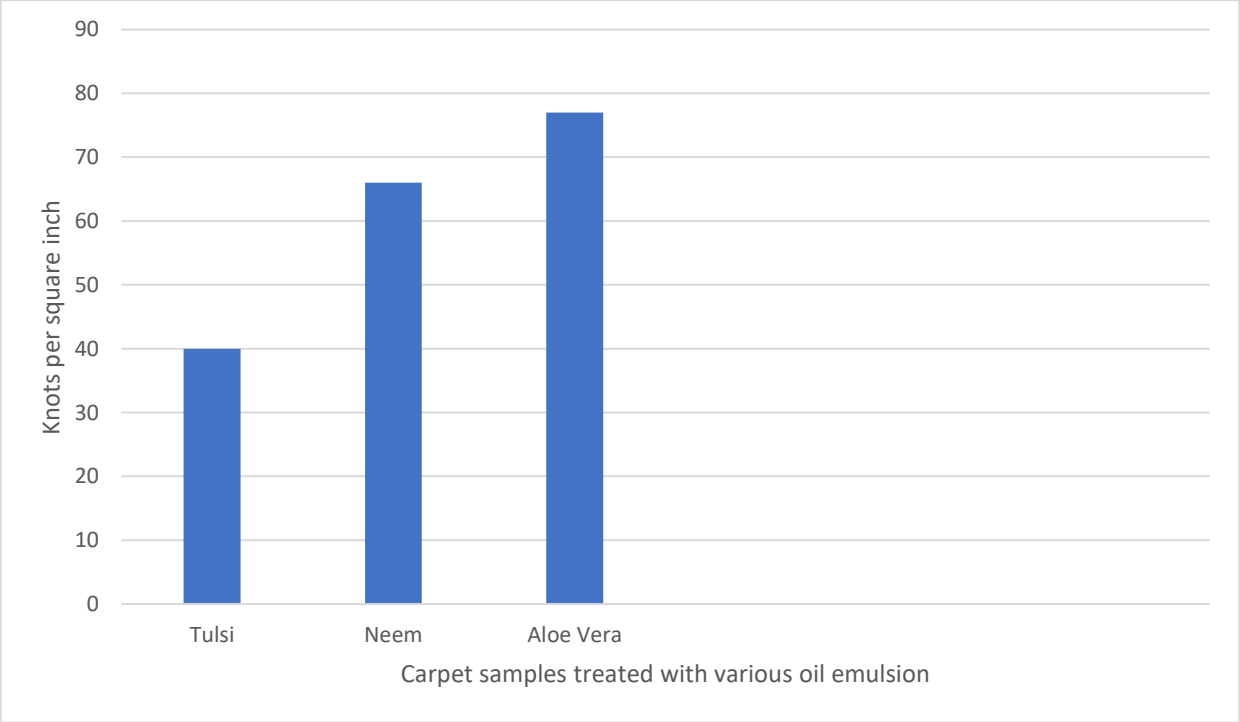


**Figure 2: Effect on Knot Density of Carpet after Oil application**

### 4.2 Characteristics of Nano-emulsion

Particle size analysis of Neem, Basil and Aloe vera oil having concentrations of 1%, and 5% each was 30 nm each at oil to surfactant ratio of 1:1. This indicates extremely fine particle size which is unaffected by increasing the concentration of oil from 1 to 5% in nano-emulsion.

### 4.3 Thermal Stability

A thermodynamic study of nano-emulsion was done to check the effect of temperature on the emulsion. All three oils were kept at $4^0$C for 24 hours and then at $40^0$C for 24 hours. Then, observations showed that no separation occurred between the oil and water phases due to thermal changes proving its stability towards temperature change as shown in Figure 3. This indicates that the oil emulsion is stable at a varying room temperature level (Figure 3.1), making it suitable for application by local weavers after the carpets are made.

**Figure 3.1: (a), (b)** **Figure 3.2: (a), (b)** **Figure 3.3: (a), (b)**

Fig. 3: 3.1 Thermal stability of neem oil, nano-emulsions with concentration (a) 1% (b) 5%. Fig 3.2 Thermal stability of basil oil, nano-emulsions with concentration (a) 1% (b) 5%. Fig 3.3 Thermal stability of aloe vera oil, nano-emulsions with concentration (a) 1% (b) 5%

### 4.4 FTIR Analysis

Many secondary plant metabolites, including classes of compounds like isoprenoids (terpenoids containing limonoid structures) and non-isoprenoids (tannins), have been implicated in the antimicrobial activities of the tested neem oil extracts. As shown in Fig. 4, the aliphatic C-H stretch due to the neem oil emulsion was demonstrated by a peak at 2857–2925 $cm^{-1}$. The triglyceride ester of the neem oil emulsion showed a C=O stretch at 1740 $cm^{-1}$ and a C-H bend at 1467 $cm^{-1}$. Esters were inferred to be present at peaks of 1166 $cm^{-1}$, predicted by the stretching vibration of C-O-C, and 719–723 $cm^{-1}$, which was caused by the neem oil's methylene vibration.

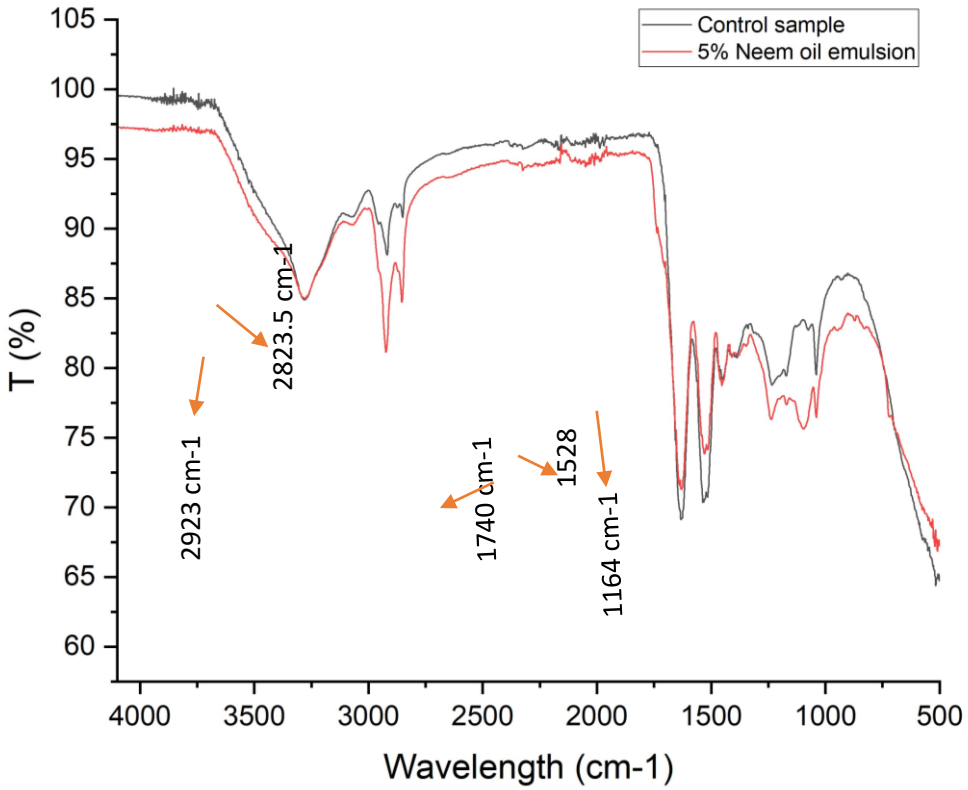


**Figure 4: FTIR analysis of Sample treated with 5% neem oil emulsion**

### 4.5 Flammability Test

As per Fig. 5, the radius effect of ignition was minimum aloe vera followed by neem and Tulsi oil. The reason could be related to the aloe vera oil being Non-Flammable with a higher flashpoint of >287°C when compared with neem (Flashpoint >200ºC) and Tulsi oil (Flashpoint >175ºC). The low radius effects of ignition indicate that the spreading of flame does not take place (Fig. 6).

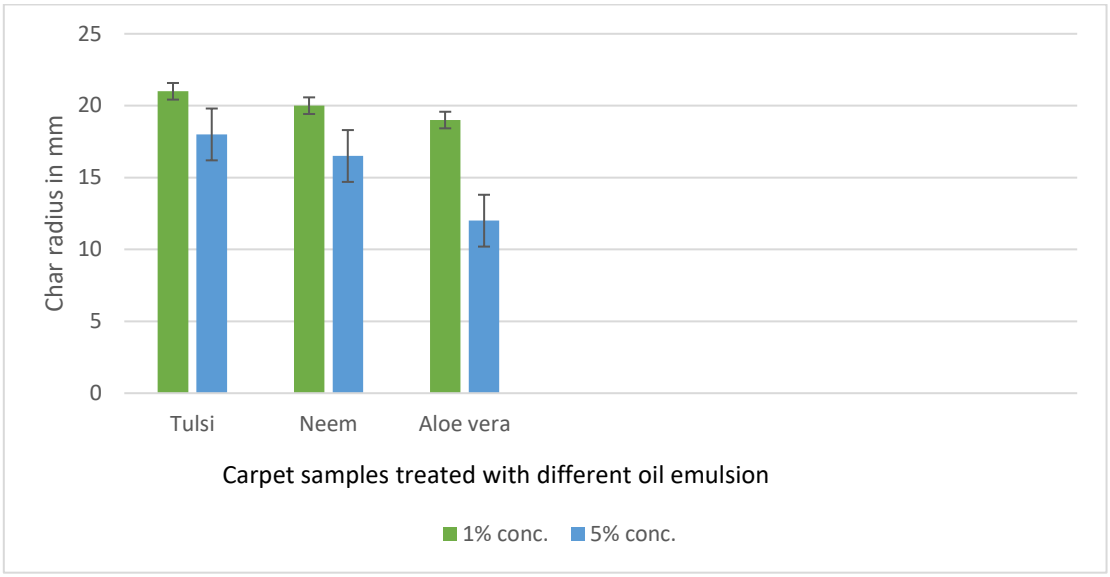


**Figure 5: Effect of Essential oil treatment on the Flammability of carpet**

**Figure 6: Flammability test of carpet samples treated with basil, neem and aloevera oil.**

### 4.6 Antibacterial Test

Antimicrobial test results against S. aureus (Gram +ve bacteria) and K. pneumoniae (Gram -ve bacteria) represent the zone of inhibition in 1% and 5% neem oil emulsion, Aloe vera oil, and basil oil emulsion. The 5% Neem oil in water emulsion treated carpet sample creates a wide zone of inhibition, followed by the carpet sample treated with 5% basil oil and aloe vera oil emulsion as shown in Fig. 7. The hydroxyl groups in neem oil structure interfere with bacterial metabolism resulting in microbial growth reduction. Neem oil tends to accumulate on the surface of fibres as its quantity increases which can be seen from Fig, making the hydroxyl groups easier for microbes to access. The carpet samples received for antibacterial property analysis after five times washable when tested as per the AATCC 100 method showed 99% antibacterial activity for both bacteria.

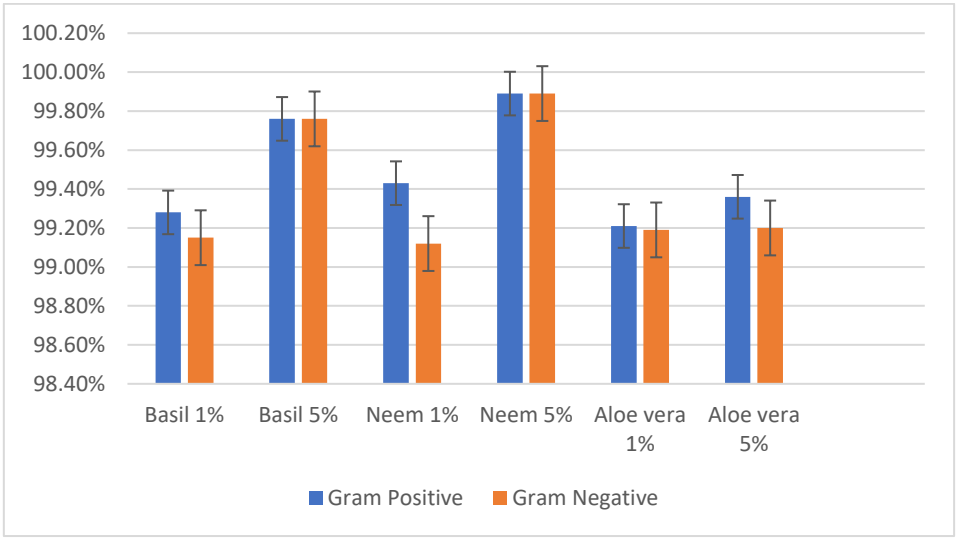


**Figure 7: Effect of Essential oil Emulsion Treatment on the Carpet Antimicrobial Activity.**

## V. CONCLUSION

The findings suggest the feasibility and usefulness of oil emulsion for its use as an antimicrobial agent in the hand-knotted carpet finishing process. The emulsion of Neem, Basil, and Aloe oil was successfully prepared in 1% and 5% concentrations having 30 -32 nm particle size and thermal stability. It was noticed that both 1% and 5% oil emulsions gave promising results of antimicrobial efficiency on treated carpets, however, carpets treated with 5% neem oil emulsion showed maximum antimicrobial activity. Neem oil has hydroxyl groups and traces of other bioactive compounds, which perform as key ingredients for antimicrobial activity. Therefore, the use of neem, basil, and aloe oil emulsion in the application of antimicrobial carpet finishing would not only reduce the dependability of hazardous chemicals but it also opens up the possibility of developing a value-added product.

## ACKNOWLEDGEMENT

The authors would like to acknowledge the support and cooperation received from the Department of Fibres and Textile Processing Technology of the Institute of Chemical Technology Mumbai.

## DECALARION STATEMENT

| | |
|---|---|
| Funding/ Grants/ Financial Support | No, I did not receive. |
| Conflicts of Interest/ Competing Interests | No conflicts of interest to the best of our knowledge. |
| Ethical Approval and Consent to Participate | No, the article does not require ethical approval and consent to participate with evidence. |
| Availability of Data and Material/ Data Access Statement | Not relevant. |
| Authors Contributions | All authors have equal participation in this article. |

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## AUTHORS PROFILE

**Mr. Raj Yadav**, M Tech in Fibres and Textile Processing Technology, ICT Mumbai. B Tech In Carpet Technology, Indian Institute of Carpet Technology, Bhadohi Uttar Pradesh. Having industrial work experience at Kaysons Export Agra (A leading carpet manufacturer and exporter) as Quality Assurance Officer for Visual and Final Inspection of carpets. Quality Control during Fabrication of Stores. Bombay Rayon Fashion Ltd (BRFL), Mumbai as Sr. executive officer - Linen, cotton, viscose fabric, processing and finishing. Conducting Quality inspection.

**Ms. Richa Khulbe**, Ph.D. scholar in Textile Chemistry; UGC Fellow at ICT Mumbai Presently working as a Ph.D. Fellow in the Department of Fibres and Textile Processing Technology at the Institute of Chemical Technology, Mumbai. Education background – Completed Master's in Fabric and Apparel Science from Lady Irwin College, Delhi University and cleared UGC JRF in 2022.

Worked as a merchandiser in the garment export house based in Faridabad and completed a few internships in product application and marketing in the textile industry. The last project was the extraction and application of starch obtained from waste cull banana (Plantain) on textile substrates which is also applied for the patent.

**Dr. Ashok Athalye**, Ph.D. (Tech) in Textile Chemistry (UDCT Mumbai), Fellow of Society of Dyers and Colourists (FSDC-UK) and Fellow of Indian Chemical Society (FICS). Presently -Professor in Textile Chemistry and Dean – Student and Alumni Affairs, at ICT. Having work experience of over 26 years in technical service for applying dyes and chemicals in textile processing. Gathered industrial competency based on the roles and responsibilities entrusted at various levels in Indian and multinational organizations. Published over 100 research and review articles in journals of international repute and made technical presentations at various seminars.