historically been regarded primarily from an economic and functional standpoint, particularly in relation to specific end uses such as safety and health considerations. The findings of various surveys (5,6) suggests that the inclusion of functional attributes in apparel products is deemed essential. The antimicrobial attribute of fabric holds significant importance in various applications, particularly in the domains of health and hygiene. In order to cater to the discernment and demands of consumers, textile products that incorporate synthetic antimicrobial agents, including triclosan, organometallics, phenols, and quaternary ammonium compounds, have been devised and are presently accessible in the commercial market. While synthetic antimicrobial agents have demonstrated efficacy in combating microbial infections, it is important to acknowledge the presence of accompanying adverse effects (7). Consequently, it is imperative to cultivate antimicrobial textiles that are founded upon environmentally sustainable agents. Chitosan, a naturally occurring biopolymer, has demonstrated significant utility within the scope of this particular field of investigation. Several recent studies (8, 9, and 10) have suggested that India, a renowned hub of biodiversity on a global scale, boasts an impressive array of flora, encompassing a staggering range of 15,000 to 20,000 plant species that possess significant medicinal properties. Various components derived from different parts of these plants have been found to possess notable antimicrobial properties (8). Several of these compounds exhibit bactericidal properties, while others function as bacteriostatic agents. Bamboo fibre is known as "Air Vitamin" or "long-lived element" in China. It contains anions that are extremely beneficial for purifying blood, calming the nervous system, and alleviating allergic symptoms, which all contribute to enhancing the health of the human body (9). Bamboo is composed entirely of natural cellulosic fibres. It is one of the quickest-growing plants that does not require pesticides, fertilizers, or herbicides, and requires less water to thrive. The fibre is wholly biodegradable and a solution to many environmental issues in the textile industry, as its production and decomposition have no negative environmental effects. Bamboo fibre contains an bio agent known as 'Bamboo Kun' (11). During the production of bamboo fibre, bamboo cellulose is combined with bamboo fibre to create a naturally antibacterial, bacteriostatic, and deodorising fabric. Fabrics produced from bamboo have many desirable qualities, such as permeability, hygroscopability, and a soft feel, which makes them an excellent environmentally friendly fabric. When bamboo fibre is combined with cotton or any other fibre, its properties increase and can be utilised for a variety of purposes (12). The primary objective of my current pre-print is to formulate a sustainable and environmentally conscious antimicrobial finish derived from plant extract of S.Asoca, with the specific intention of implementing it in the realm of Bamboo textiles. The application of the plant extract was conducted on fabrics made from Bamboo. Subsequently, the antimicrobial efficacy of these treated fabrics was evaluated using standardized test methods, both quantitatively and qualitatively.(13,14)

2. MATERIALS AND METHODS

S. asoca, a naturally occurring biocide known for its therapeutic properties, was chosen for this research project and gathered from the forests of Gandhinagar. Following a thorough washing under running tap water, the gathered leaves were dried in the sun for three days in an effort to reduce the amount of moisture they contained. After being reduced to a very fine powder, the leaves were screened to remove any impurities. The powder of 20 grammes of S. Asoca leaves was suspended in 100 millilitres of methanol, and the mixture was allowed to incubate at room temperature for one full day. Following this step, the supernatant was filtered twice with Whattman No. 1 filter paper, and the filtrate was subsequently utilized as a herbal biocide of leaves extract for the treatment of bamboo fabrics.

To accomplish uniform absorption and thorough wetting of the solution during padding, 100 percent bamboo cloth was utilized. Before applying an antibacterial finish, foreign material was removed from the woven bamboo fabric. The bamboo fabric was cut to a sample size of 10 x 10 cm. The bamboo fabrics were then treated with this methanolic extracted herbal biocide by pad-dry-cure process. Fabric were first soaked at optimized process conditions with various concentrations of SA i.e. Solution 1 (10gpl), Solution 2 (15gpl) and Solution 3 (20gpl), 90^{o}C for 60 minutes and pH-7. Along with a crosslinking agent using the 3 dip-3 nip method, and the wet uptake was 70%. The dry temperature and time were, respectively, 85°C and 15 minutes to remove the moisture. The curing procedure lasted 3 minutes at 140 degree Celsius. After curing, the item was then desiccated. Then finished fabric samples were further tested for antimicrobial activity as per the standard test methods.

2.1 Evaluation of antimicrobial effectiveness

Both qualitative and quantitative methodologies were used to evaluate antimicrobial activity. The Following are descriptions of the testing procedures utilized in this investigation. The strategy ensures that techniques are standardized and that results can be reproduced. Using the AATCC standard test method 100:2004, a quantitative evaluation of the antibacterial efficacy of antimicrobial agents against Gram-positive bacteria Staphylococcus Aureus (S. Aureus) and Gram-negative bacteria Escherichia coli (E. Coli) was conducted.(10,11)

2.1.1 Qualitative evaluation- Asessment of Antibacterial Activity of the treated textiles

Using AATCC standards, the antibacterial activity of the treated bamboo samples was evaluated – A parallel streak test using AATCC test method 147-1988 was conducted. To assure intimate contact with the agar surface, the test sample was gently pressed transversely across the five inoculated streaks. Plates were incubated at 37 degrees Celsius for 18 to 24 hours.

The inoculated plates were inspected for growth inhibition along the inoculum lines beneath the fabrics and for a distinct zone of inhibition beyond the fabric edge. Using Equation 1, the average width of the zone of inhibition surrounding the test specimen was determined in millimetres.

$$\text{Zone of inhibition (mm)} = (T - I)/2 \quad \ldots(1)$$

Where T denotes the breadth of the inhibition zone and I denotes the width of the specimen.

2.1.2 Quantitative evaluation - Assessment of Percentage Reduction (AATCC 100-2004)

In order to conduct the tests, specimens were collected and then sliced into circular swatches with a diameter of 4.8 -0.1 cm, which is the required standard. The samples to be examined were placed in a clean petri dish, and then 0.1 millilitres of the test inoculum were transferred to the dish with the help of a micropipette. After that, both the treated and untreated swatches were placed in separate containers filled with sterile AATCC Bacteriostasis broth and given their own labels. After that, the flasks were shaken in an incubator at room temperature for a period of twenty-four hours. Approximately 0.1 millilitre of the sample from each step of the dilution process was spread out onto sterile AATCC Bacteriostasis agar plates and then the process was repeated 12 times.

After being inoculated, the plates were kept in an incubator at 37 degrees Celsius for a whole day. The plates that had been inoculated were inspected to see if they contained any bacterial colonies.

The formula $R = 100\,(B - A)/B \quad \ldots\ldots\ldots\ldots(2)$ can be used to determine what percentage of germs have been eliminated as a result of the finishing.

R is the percent of reduction

A is the total number of bacteria that were reclaimed from the injected treated sample.

B equals the total number of bacteria that were reclaimed from the injected untreated swatch.

2.2 Wash Resistance Evaluation:

After multiple laundering cycles, the antibacterial effectiveness of the resulting fabric was evaluated. The durability of the antibacterial finish was evaluated utilizing a launder-o-meter in accordance with IS: 687–1979 Test No. 1 with neutral detergent at a concentration of 5gpl at 80ºC for 30 minutes with a material-to-liquid ratio of 1:40, followed by rinsing, washing, and drying. Using the AATCC 100 technique and up to 25 laundering cycles, the antibacterial activity of the test samples was evaluated following drying.

2.3 Electron Microscopy by Scanning:

Scanning electron microscopy (SEM) enables the imaging of surface properties of a sample by sending it through an electron beam. The resolution and depth of field of SEM are superior to those of an optical microscope. As a consequence, stunning, seemingly three-dimensional images were created. The surface morphology of the control sample and the optimized sample (solution-3) was analyzed using SEM (JEOL JSM IT 200) technology with a magnification range of 1000X to 10,000X and a resolution of approximately 10nm. Both the surface and cross-sectional images of the samples are clearly visible.

3. RESULTS

After being exposed to different concentrations of biocide (S.Asoca), the specimen demonstrated exceptional antibacterial activity (Figure 1). The Biocide-treated samples with eco-friendly approach demonstrated a significant reduction in the number of bacterial colonies (Figure 2) and a distinct zone of bacterial inhibition. The fabric treated with a natural biocide (Solution-3) exhibited the highest level of antibacterial activity and bacterial reduction against Gram-negative and Gram-positive test organisms, respectively. Specifically, Escherichia coli and Staphylococcus aureus. The findings also indicated that the antimicrobial finish durability of the treated sample was 98% after 25 washings.

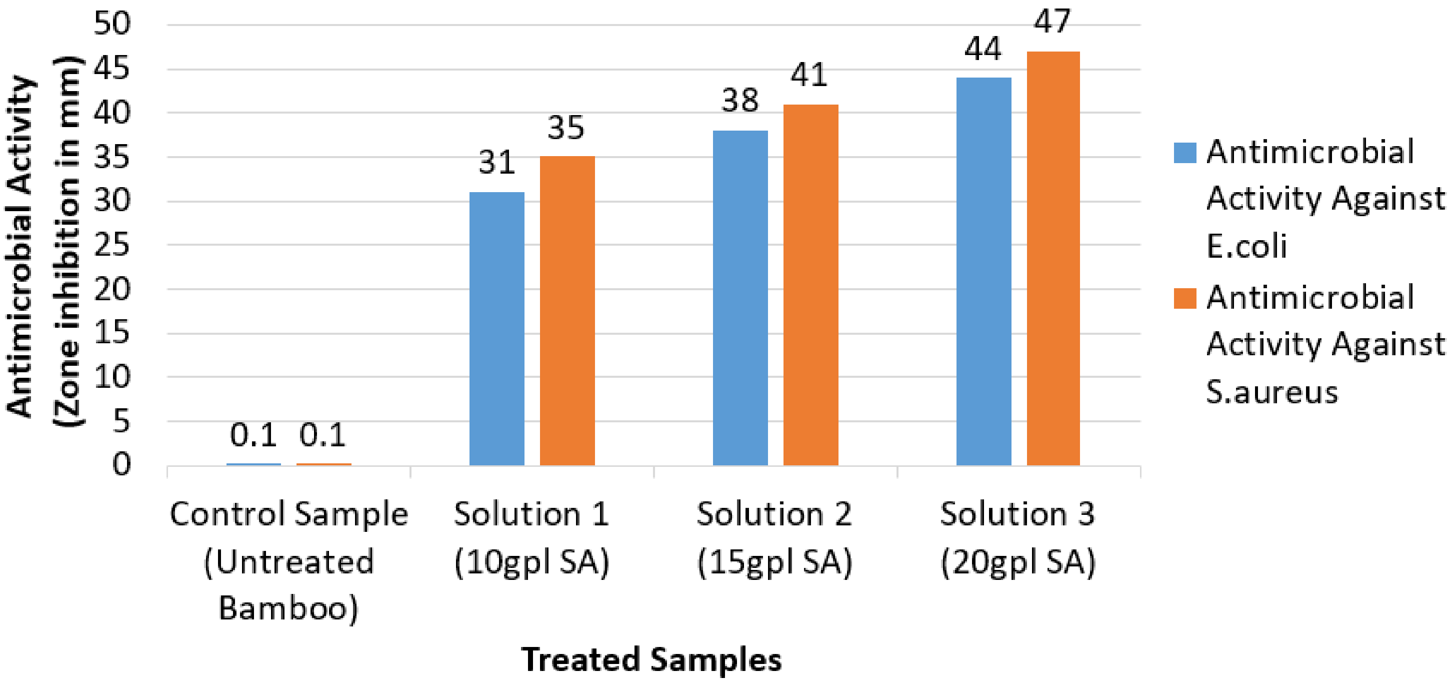


Figure 1 Compares the Qualitative Antibacterial Activity of Untreated (Control Sample) and Treated (with Solution 1, Solution 2, and Solution 3) Textiles.

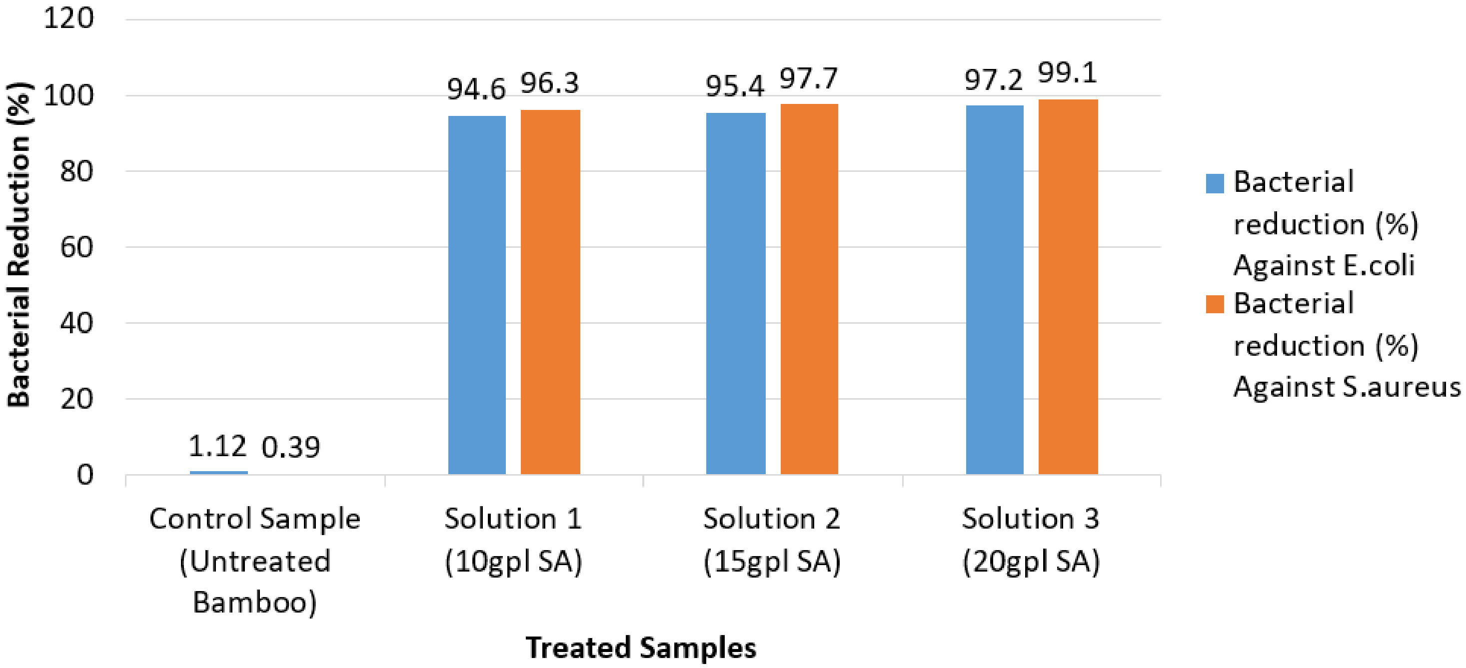
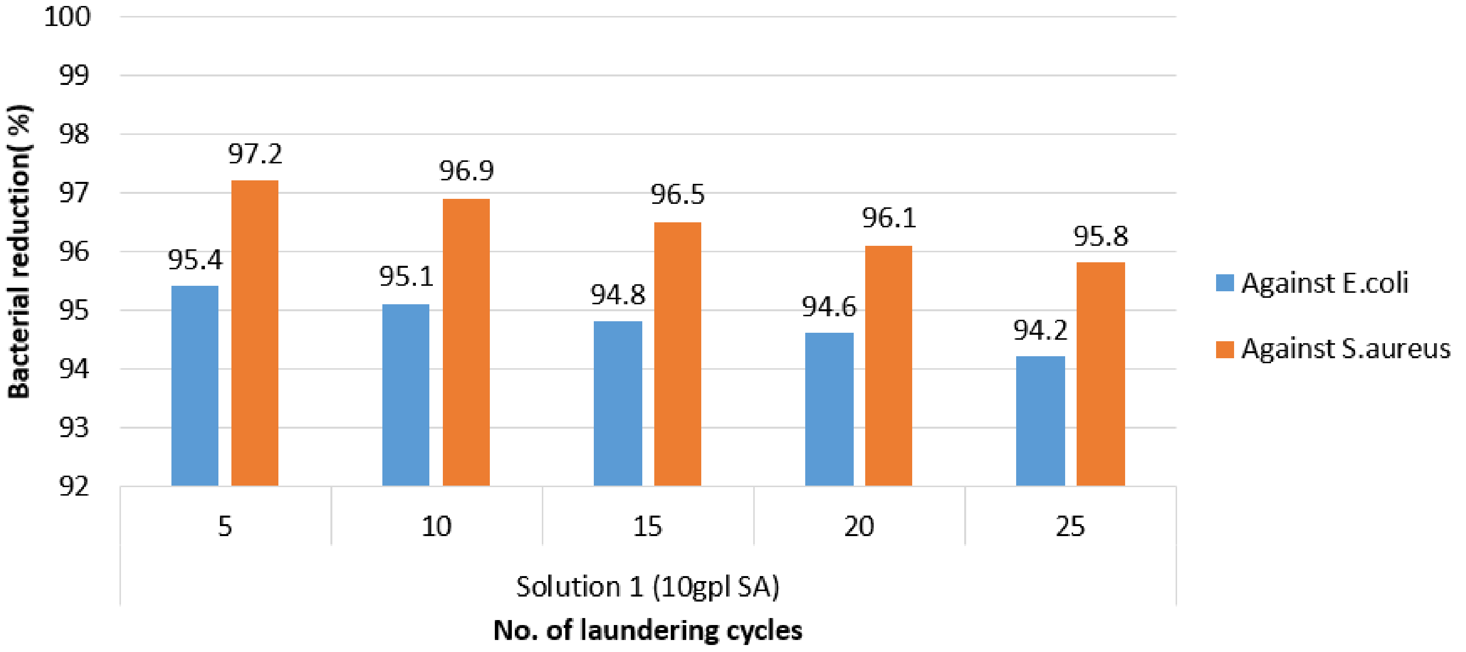
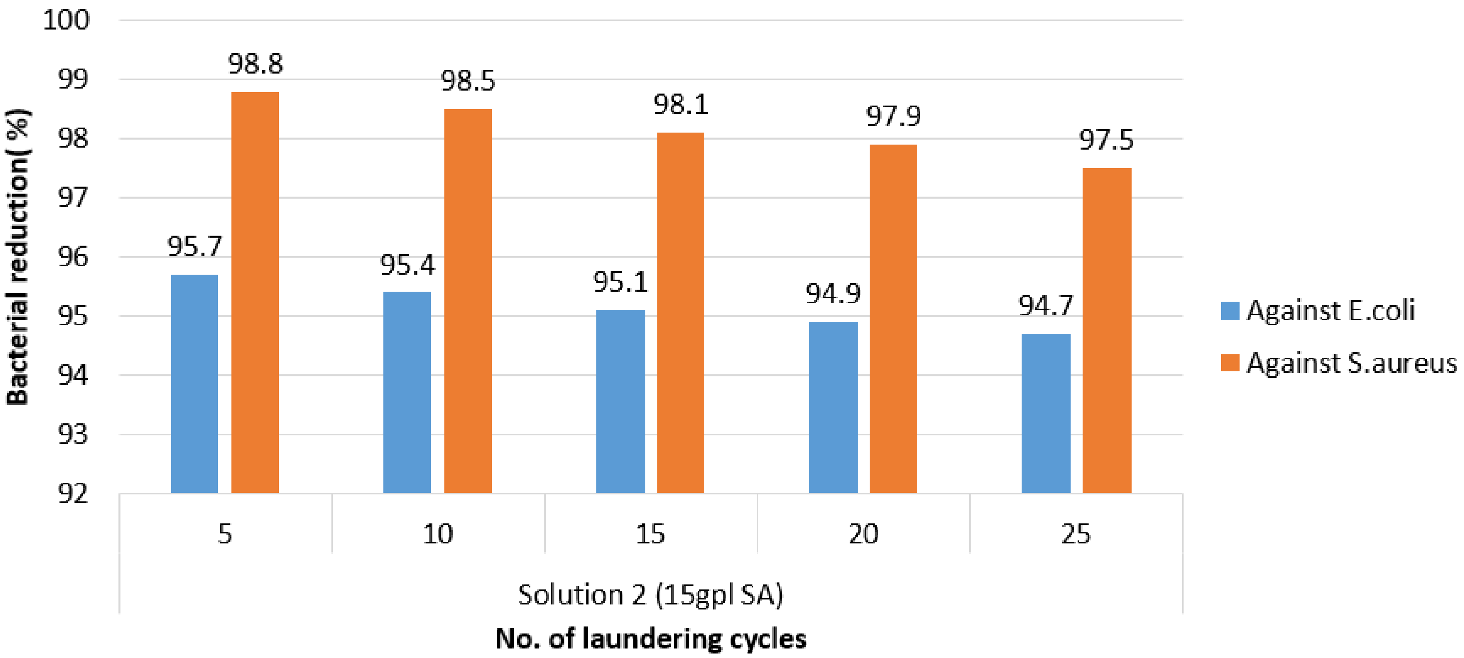


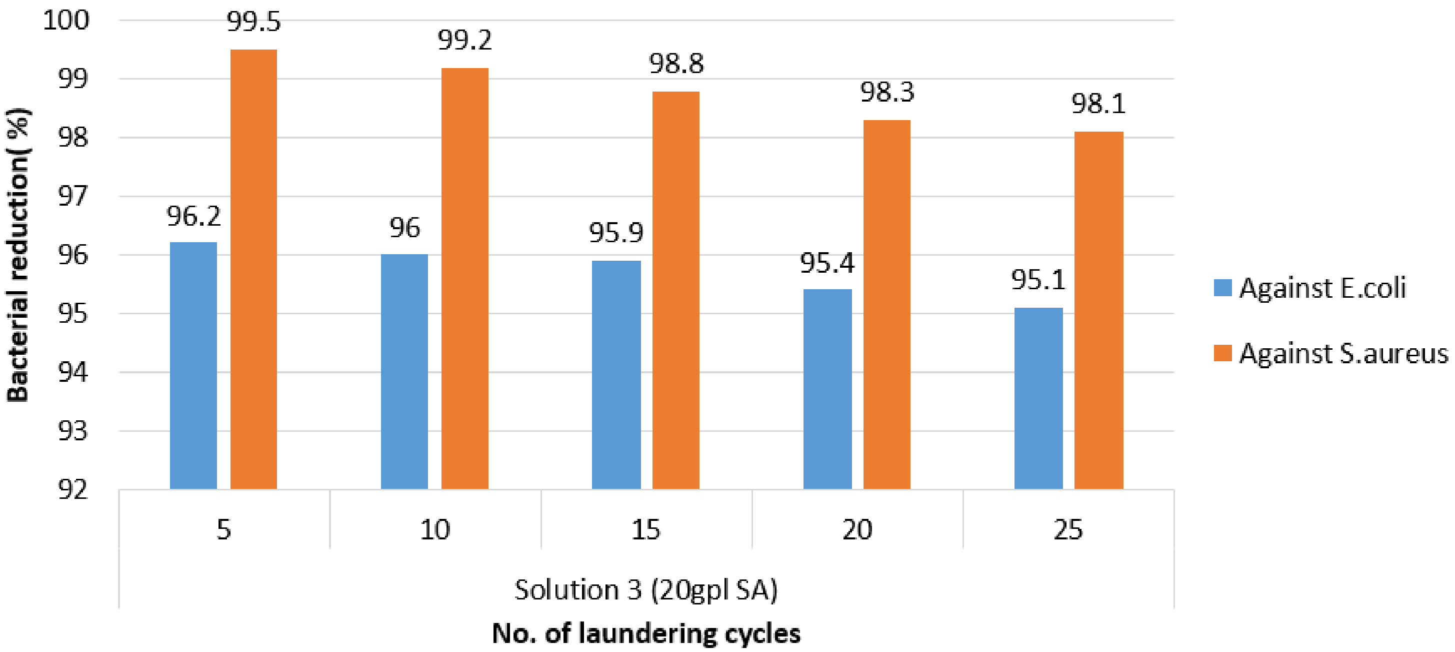
Figure 2 Compares the Quantitative Bacterial Reduction of Untreated (Control) and Treated (with Solution 1, Solution 2, and Solution 3) Textiles.



(a)



(b)

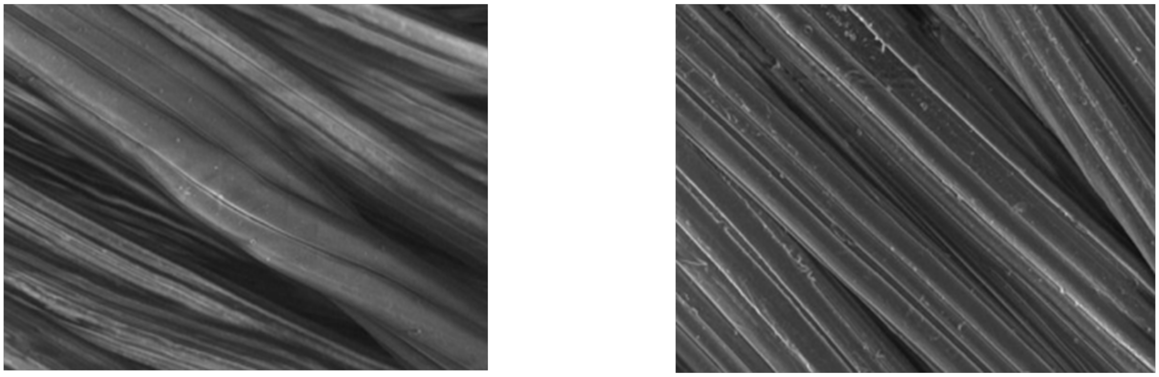


(c)

Figure 3 Wash durability of untreated (control sample) and treated (with various solutions (a), (b), and (c)) fabric after 5, 10, 15, 20, and 25 washing.

Figure 3 depicts the results of the Wash Durability Tests that were used to calculate the percentage decline in antibacterial activity after 25 washing cycles. The samples of fabric that had been treated with all of the other antimicrobials used in research were laundered. Up to 25 wash cycles, the fabrics treated with 20gpl biocide Figure3(c) demonstrated the greatest reduction in microorganisms. However, as depicted in figures 3(a) and (b), the treatment with the lower concentration of biocide also exhibited exceptional antibacterial activity and durability to laundering, as the treated bamboo samples reduced the percentage of microbes by 95 to 98% up to 25 laundering cycles.

Using scanning electron microscopy (SEM), the antibacterial properties of biocide-treated fabric with a higher concentration and bacterial proliferation on other treated fabrics were compared to untreated fabrics (figure 4). The ability of the biocide to cross-link with bamboo fabrics is plainly demonstrated by SEM micrographs, as shown in the figure.



(A) **(B)**

Figure 4: SEM image of untreated (A) and treated (B) specimens of optimized recipe (solution 3)

4. DISCUSSION

Due to the formation of a cyclic anhydride, followed by the formation of an ester with the hydroxyl group (-OH group) of the cellulose macromolecule, the treatment is resistant to washing and the antimicrobial activity remains after 25 launderings, as demonstrated by studies on the durability of the treatment. With the help of crosslinking agent (BTCA), the esterification of bamboo cellulose with biocide involves two steps: (i) the production of a cyclic anhydride by dehydration of two adjacent carboxylic acid groups, and (ii) the subsequent esterification of the acid anhydrides with the hydroxyl groups of the cellulose macromolecules to form an ester. The formation of a covalent bond between the crosslinking agent, antimicrobial agent, and cellulosic chains enhances the laundering durability of the antimicrobial treatment. Bamboo fabric is completely biodegradable.

5. FUTURE SCOPE

A heightened consumer awareness of health and hygiene has increased the demand for antimicrobial textiles. Healthcare is a serious enterprise that is influenced by more than just medical practitioners. The susceptibility of textiles to attack by microorganisms would result in numerous cross-infections. In recent years, the quantity of biofunctional textiles with antimicrobial activity has increased significantly. By establishing a physical barrier, an antimicrobial finish on fabrics can reduce the transfer of microorganisms to the wearer. Medicinal plants play an essential role in fitness care programmes, particularly in developing countries.

Natural biocide present in the leaves, stem and flowers are the backbone of these historical drug structures. Quality and standardization of medicinal plants are essential for improved treatment in traditional systems of medicine. Step-by-step pharmacognostic studies can be used to achieve standardization. The pharmacological and phytochemical evaluation of a primitive drug is essential for determining its inherent potency. To ensure the safe use of these pharmacological therapies, it is essential to establish first-rate protection and efficacy standards as a prerequisite.

6. CONCLUSION

Medications derived from plants have been used since the dawn of time. India is rich with medicinal plants. The medicinal properties of textiles treated with plant based natural biocide are beneficial to the skin. This study evaluated the antibacterial properties of plant based herb (S.Asoca) treated to the bamboo textiles. The treated samples with herbs inhibited bacterial growth in comparison to untreated samples and demonstrated excellent resistance to a variety of microorganisms. After 25 washes, the antimicrobial property of the treated sample exhibited remarkable washing resistance.

Among the three different concentration of biocide, Solution 3 (20gpl S.Asoca) produced a strong antibacterial finish with outstanding fastness and stability on bamboo fabrics. It also exhibited a significant reduction in colonial growth and a distinct zone of bacterial inhibition. It has enhanced antimicrobial efficacy. The number of test microorganisms was reduced by 98% after 25 cycles of washing. According to the findings of the study, the modified materials could be used for textile functional finishing applications.

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