CHAPTER 5

CONCLUSIONS

AND

FUTURE SCOPE

5.1 CONCLUSIONS

Development of hygiene nano-composites, using the green-way synthesized silver nanoparticles (AgNPs) with CP leave extract was aimed in the present study. The outcomes for the series of experiments are summarized here.

1. The chemical synthesis (CS) of the $AgNO_3$ has produced a noteworthy amount of nanoparticle by bottom-up (reverse) method (CS-2) compared to forward and reduction approaches. The colloidal colour was changed from colourless to yellowish and confirmed occurrence of nanoparticles. Going in accordance, the reverse green synthesis (GS) method has generated admirable nanoparticles (GS-2). The subjective colour change validation was supported by the SEM micrographs. A uniform dispersion of AgNPs with rarely occurring aggregation was noticed even though ten times more CP extract was consumed than $AgNO_3$ during reverse mode of synthesis. This pro-rata of participants also persuaded economy to the newly synthesized colloidal.

2. A prototype PV-nonwoven nano-composite @PV-AgNPs/CP was successfully prepared using a cold dipping technique. The ESEM micrograph obtained for AgNPs/CP loaded fabric using the 'ImageJ 1.53a' program has revealed the average particles size of 160nm without an accumulation. It has also witnessed a good level of AgNPs deposition on the PV-nonwoven fabric.

3. An elemental analysis (EDAX) of PV-AgNPs/CP has illustrated a prominent peak of metallic silver nanoparticles for AgNPs/CP treated sample 01 and endorsed penetration of AgNPs in the nonwoven structure.

4. The FTIR spectrum characterization peaks for the PV-AgNPs/CP nano-composite has exhibited a similar chemical composition in case of untreated (sample 00) and treated (sample (01) due to major share of common base material. However, additional chemical compositions, such as aromatic amine (C-N) stretching vibration and phenolic (O-H) bending vibration endorsing presence of AgNPs/CP, were also visualized.

5. The PV-AgNPs/CP nano-composite (Sample 01) has executed considerable antibacterial activity against both bacterial cultures Staphylococcus aureus (23.75mm) and Escherichia coli (24.5mm), compared to values realized for usual chemical based AgNPs loaded composites. This has proven qualitative strength of new green channel of AgNPs synthesis.

6. The physical parameters revealed no remarkable change in fabric thickness after treatment, but GSM has shown a small rise even at the nanoscale addition, which is contradictory to the normal trend.

7. The selected PV-nonwoven with the added prototype green functional elements has shown arbitrary but not much higher fluctuations in machine-direction (MD) and cross-direction (CD) bending modulus. Thus, rendered the material suitable for bio-medical applications.

8. Air permeability of the base fabric was reduced in quite a low amount; by 1.99% only on AgNPs/CP deposition. It was more expectedly to be the outcome of inbuilt structural variations of the material itself rather than treatment. This will not affect adversely its use as a bio-medical textile material.

9. The PV-AgNPs/CP nano-composite has executed preferred 'excellent' moisture management capabilities for bio-medical textile and is classified as a 'moisture management fabric' than the reference untreated fabric.

10. Application of the AgNPs/CP nanoparticles has not positively contributed in the UPF rating of the PV-nano-composite. However, percent UVA and UVB transmittance was reduced to 20.75% and 9.18% and made the material more protective against UVA and UVB type radiations.

11. Colour of all the colloidal solutions synthesized with major scale silver nitrate ($AgNO_3$) salt add-on was turned from brown to black, indicating formation of the undesirable macro molecules due to agglomeration of unstable nanoparticles after 24 to 48 hours of synthesis. Thus, pointed towards inappropriateness of higher level $AgNO_3$ and CP extract add-ons in newer synthesis.

12. All of the major scale $AgNO_3$ add-on colloidal samples except sample A1 (E05S00) have shown good bacterial inhibition against both SA and EC bacterial cultures up to 72 hours. The highest average ZOI value has gone in the account of colloidal solution 'E10S01 (B2)' made with 10% CP extract (green medium) concentration and 100mM $AgNO_3$. This was attained due to presence of higher quantum of $AgNO_3$ and CP extract inherently antibacterial in nature.

13. Sample A1 (E05S00) prepared without $AgNO_3$ was failed to achieve bacterial inhibition against SA bacteria but demonstrated average ZOI of 12mm against EC bacteria in the initial 24 hours. However, antibacterial activities were diminished to zero after the next 24 hours holding time.

14. The MTT assay cytotoxicity test displayed the favourable much higher viability of the cell line at the chosen 5 to 20 percent concentrations of the CP leave extract than the CP pure latex. The viability of the cell line was decreased with the increase in the concentration of CP leave extract. So, cell survival point of view the lowest 5 percent concentration of CP leave extract was considered as best amongst all. But its ineffectiveness against bacteria has made next higher-level CP concentration; E10 with highest antibacterial potential as an optimum choice.

15. All of the colloidal solutions formed in the first set of the minor scale trails have shown a fuzzy milky brownish colour change to validate the formation of AgNPs at the moment of synthesis during visual judgment test. However, stability of the colloidal solutions E10S0020 and E10S0040 was only persisted for a week and sustained up to a month only. Thus, substantiated poor efficacy in meeting the targeted performance.

16. The UV-VIS Spectroscopy conducted for the first minor set samples has shown broad but weak peak between 400 and 600nm (or <600nm) with increased molarity of the $AgNO_3$. This witnessed presence of undesirable poor-quality AgNPs on agglomeration of basically small or medium-sized nanoparticles.

17. The DLS spectra for all of the first minor scale colloidal solutions under observation have shown a broad polydisperse type of distribution with the preferable AgNPs size less-than 100nm (range from 28.8nm to 58.7nm). This has indicated a large diversity of particle sizes existence.

18. Colloidal solutions E10S0020 (E1) and E10S0040 (E2) have demonstrated good antibacterial activity against SA and EC bacterial cultures amongst the first minor set samples. This behaviour has supported better antibacterial activities with the use of low add-on of $AgNO_3$ for constant 10% concentration of CP leave extract.

19. Formation of AgNPs in second minor scale colloidal was demonstrated by a milky-fuzzy brownish colour at the time of synthesis. Colloidal solutions E10S0010 and E10S0015 have demonstrated good AgNPs stability even after six months with a little but still acceptable colour change. Except these two, rest of the sample's stability lasted maximum for a week.

20. The UV spectra peak observed for the sample E10S0010 was stronger, sharper, and narrower, with a maximum absorption in the 400–450nm wavelength range, advocated good quality smaller nanoparticles formation without agglomeration in the group. A wider and stronger peak between 190 and 400nm usual for CP leave extract was noted in the sample E10S0000. The DLS spectra for E10S0010 (F4) colloidal solution have shown the most ideal silver nanoparticle size distribution of 25.8nm. This has endorsed optima for $AgNO_3$ as 10mM in the group.

21. The highest average ZOI value; 18.0mm against SA and 21.7mm against an EC bacterial culture, was recorded with the colloidal solution E10S0010 (F4). The sample E10S0000 (F1) synthesized using CP leave extract (10%) only has shown average ZOI value of 16.0mm against SA and 19.3mm against EC bacterial cultures and proven its individual antibacterial strength.

22. The colloidal solution E10S0010 has an 84% cell survival rate, which is regarded to be non-toxic (>80% is significant). The cell viability of the colloidal solutions prepared with very low $AgNO_3$ add-on E10S0001 and E10S0005 was quite high (90% and 88%, respectively). The optimum CP leave extract (E10) has demonstrated 92%

cell viability witnessed its non-toxic characteristic. Thus, both the participating constituents in prototype green synthesis were found not harmful to the user if employed in a bio-medical product.

23. The GC-MS analysis endorsed presence of N-Decanoic Acid ($C_{10}H_{20}O_2$) responsible for antibacterial activity in the 10% concentration CP leave extract. Presence of amino acids, citric acid, flavonoids, phenolic compounds, terpenoids, heterocyclic compounds, enzymes, peptides, polysaccharides, saponins, tannins, etc. were also detected in the extract found responsible for reduction and capping of nanoparticles. Altogether proven potential of the innovative medium in AgNPs synthesis.

24. A virtue-based technique, similar to the one used in phase-II, was used successfully to deposit AgNPs on the hydrophobic PP and hydrophilic PV non-woven fabrics most popularly used in different bio-medical applications. So, this method was regarded as an appropriate for the prototype bio-medical nano-composites development.

25. The Physical parameters, low-stress qualities, comfort-associated attributes, ESEM micrographs, and FTIR spectrum characterization peaks all have shown more or less comparable behaviour with reference parent samples. The additional component (AgNPs) density caused significant but end use point of view tolerable changes in GSM and thickness. The observation was supported by the lesser changes seen with the lighter CP extract loaded composite values.

26. The statistical analysis has shown that there were no statistically significant differences occurred between the AgNPs/CP and CP extract treatments for low-stress characteristics measured in the Machine-wise Direction and Cross-wise Direction.

27. The air permeability of treating nonwoven textile materials with CP leave extract and AgNPs/CP was lowered due to coverage of higher specific surface by nanoparticles and found statistically significant also. But not to the extent which can hamper their performance as a bio-medical textile material.

28. Most of the composite samples including the control have shown 'very poor' rating for OMMC. The base materials were also classified as 'water proof fabrics', with poor

moisture management, and thereby graded as 'very poor'. Only the 'moisture management fabric' @PV40-AgNPs/CP nano-composite has shown better capacity to handle water in the group mainly due to presence of hydrophilic viscose fibers in the structure.

29. The efficiency and durability of the antibacterial activity mapped against SA and EC bacteria were zero invariably for all the selected base fabrics as per expectation. However, they were visualized in good quantum for all the CP treated composites which has endorsed potential of the selected novel green channel in developing hygiene bio-medical materials. The extent of antibacterial activities got further enhanced in the presence of silver; AgNPs/CP treated samples as anticipated. The ZOI values noted in each category of sample are much higher than the chemically synthesized AgNPs treated bio-medical materials (~10 – 15mm) in commercial use.

30. The applications of CP leave extract and AgNPs/CP have shown preferable statistically significant improvements in the UV transmittance profile of the studied nonwoven textile materials.

31. The ESEM micrographs have substantiated the AgNPs deposition method adopted in the present study as a satisfactory for a virtuous deposition of AgNPs on the difficult to treat kind PP as well as more user-friendly PV non-woven fabric.

32. The FTIR spectrum peaks associated with phenolic and aromatic amine groups seen clearly have advocated success about the incorporation of AgNPs/CP into PV based composites as well as difficult to induced type all the PP based nano-composites.

5.2 RECOMMENDATIONS/SCOPE FOR THE FUTURE WORK

I. The present work was focused to develop disposable class of bio-medical textile materials only. So, the extension works with the non-disposable woven and knitted structures can be targeted. The performance sustainability of the AgNPs/CP into these structures on immediate loading and after prescribed number of washing cycles need to be worked out.

II. The base material selection was biased by the type of fabric; nonwoven used during the study. Thereby, extent of hygiene attains and retains with other popular materials like cotton, polyester, woollen etc. used in different formats in hospital environment need to be explored with this novel green channel.

III. The CP leave extract has proven its antibacterial efficacy in the absence of silver also. So, it should be further analyzed to avoid undue utilization of costlier and toxic silver or other metallic mediums.

IV. The healing capabilities of CP extract in wound care and diabetes is well-known and also mentioned by various investigators in literature. The limitations of medical permissions restricted to explore this region during the present study but the collaborative work with medical field can give new heights to this valuable medicinal but wild plant.

V. It is possible to produce the antibacterial bio-medical products with lower material and production costs due to the abundant and free availability of CP leave. In light of the mass production of CP treated and AgNPs/CP treated fabrics used in various bio-medical applications, studies for cost efficiency can be conducted.