



MICROBIAL DEGRADATION OF SANITARY NAPKINS: A SUSTAINABLE APPROACH

¹Sakshi R Gaikwad, ²Samruddhi P Joshi, ³Prince Kumar Ray, ⁴Devkirani P Pawar

¹Student, ²Student, ³Student, ⁴Assistant Professor

Department of Biotechnology & Bioinformatics,

Deogiri College (Autonomous), Chhatrapati Sambhajnagar, India – 431005

Abstract: Biodegradation refers to any physical and chemical alteration in a material due to microorganisms. Both natural and synthetic plastics undergo degradation through the actions of microorganisms like bacteria and fungi, which utilize their enzymatic processes to break down polymers. In urban India, nearly 89.4% of women used sanitary napkins, while 77.3% of women in rural areas did the same. Around 375 million girls and women in reproductive age most of whom menstruated, disposed of an estimated 1.021 billion pads each month, with a significant portion being non-biodegradable. Approximately 123 billion disposable sanitary pads are produced annually, and their disposal has become a significant issue. These pads consist of plastic substances like polyacrylate absorbent polymer gel, polyethylene, polypropylene and propylene glycol. The objective was to break down these sanitary napkins using bacterial and fungal isolates. Both in-vitro degradation under controlled settings and in-vivo degradation in environmental conditions were executed revealing higher degradation efficiency in certain bacteria such as *Bacillus subtilis*, *Pseudomonas aeruginosa*, *Clostridium titani* and fungi like *Aspergillus niger*. FTIR (Fourier-transform infrared) spectroscopy was used to analyze the chemical bonds and changes across various functional groups.

Index Terms- Sanitary napkins, Sustainable degradation, Bacterial isolates, Fungal isolates, Waste management.

I. INTRODUCTION

At present, the globe is encountering a significant issue with the carbon footprint of feminine hygiene products [1]. Due to the vast quantity of non-biodegradable waste disposed of in landfills, harmful gases are released into the atmosphere [2,3]. In today's world, everyone is focused on establishing an eco-friendly environment by minimizing environmental issues and pollution in nature. Moreover, health and hygiene are also extremely important for individuals [4]. Menstruation is a natural biological process characterized by the regular release of blood and mucosal tissue (menses) from the uterine lining through the vagina, typically occurring every 28 to 35 days from puberty to menopause. To manage this, absorbent materials known as sanitary napkins are used to soak up menstrual discharge [5]. The key requirements for feminine hygiene products include high absorbency, odor control, leak prevention, and the ability to retain menstrual fluid securely. These products are designed to offer a comfortable and stationary fit, ensuring aesthetic appeal while enhancing the health and lifestyle of women by promoting confidence and well-being [6]. They are essential for soaking up menstrual blood and keeping it off the body, which helps prevent infections and promotes hygiene [7]. Conventional sanitary napkins pose considerable environmental concerns because of their non-biodegradable characteristics and the chemicals involved in their manufacturing [8]. Conversely, biodegradable alternatives use natural materials like bamboo, cotton, and hemp. Variations in material composition influence their effects on both the body and the environment [9].

Sanitary napkins comprise of multi-layered structure made up of non-biodegradable materials like polyethylene, polymeric films, wood pulps degrading environment each day, which is the leading concern of the economy. The top sheet of sanitary napkin consists of thermoplastic fiber and hydrophilic absorbent fiber, the absorbent core is made up of wood pulp and polyethylene and polymeric film used as barrier sheet are non-breakable by bacteria and poisons environment [10]. The disposal of these pads results in solid waste production, sewage clogs, and the emission of harmful gases during incineration, contributing to environmental contamination [11, 12]. Notably, pads contaminated with blood could carry viruses like Hepatitis and HIV, surviving in soil for up to six months. The combustion of sanitary products produced harmful gases, contributing to air pollution, while landfills continued to accumulate non-biodegradable waste. Furthermore, the prolonged breakdown period of plastic pads threatens both ecosystems and human health, as they can retain pathogens for long durations [13, 14].

As a result, there was an increasing need for innovative and sustainable solutions to manage the growing volume of menstrual waste. One promising approach involved microbial degradation, where certain bacteria and fungi, capable of degrading complex polymers like polyethylene and polypropylene, could be employed to break down the materials in sanitary napkins. This paper examines the microbial degradation of sanitary napkins as a sustainable solution for menstrual waste management. It explores the types of microorganisms involved, their enzymatic activity, and the potential for microbial-based biodegradation to mitigate the environmental and health impacts of sanitary napkin waste. Through this review, we aim to provide a synthesis of existing knowledge in the fields of public health, water and sanitation and solid waste management, offering a comprehensive perspective on how microbial degradation could contribute to more sustainable menstrual hygiene practices globally.

Table 1: Raw Materials Used in Sanitary Napkins and Their Impact on Environment.

Raw Material	Description	Environmental Impact
Polyethylene (PE)	A plastic material used in the outer layers and back sheet of sanitary napkins.	Non-biodegradable, contributes to plastic pollution, takes hundreds of years to decompose in landfills.
Polypropylene (PP)	Used in the top sheet, core, and other components for absorbency.	Non-biodegradable, adds to plastic waste, can leach toxic chemicals during decomposition.
Polyacrylate (Absorbent Polymer Gel)	A superabsorbent polymer used for fluid retention in the core of the napkin.	Non-biodegradable, contributes to chemical pollution in soil and water. It can release harmful substances.
Cellulose (Wood Pulp)	Natural fibre used for absorbency in some sanitary napkins.	Biodegradable but may require significant water and energy in processing. Can contribute to deforestation.
Silicone	Used in some pads for additional moisture retention and flexibility.	Non-biodegradable, contributes to plastic pollution.
Dyes and Fragrances	Chemicals used to colour and add fragrance to the napkins.	Can cause irritation, allergies, and environmental contamination due to the release of harmful chemicals.
Rayon	A synthetic fibre sometimes used for absorbency.	Biodegradable but often processed with toxic chemicals that can harm the environment.
Adhesives	Used to bond various layers of the sanitary napkin together.	Can contain harmful chemicals, contributing to non-biodegradable waste.
Packaging Materials	Typically made of plastic or laminated materials to protect the napkins.	Contributes to plastic waste and is non-biodegradable, increasing landfill waste.

II. MATERIALS AND METHODS

This segment describes the experimental setup created to examine the microbial breakdown of sanitary napkins. The research focused on isolating and identifying bacterial and fungal strains that possess significant degradation capabilities. Experiments on degradation, both in-vitro and in-vivo, were carried out to assess the effectiveness of chosen microorganisms in controlled and natural environmental settings. Analytical methods like Fourier-Transform Infrared (FTIR) spectroscopy were utilized to evaluate alterations in chemical bonds and changes in functional groups throughout the degradation process. The essential materials, microbial strains, and experimental methods applied are outlined comprehensively below.

1] In-Vivo Degradation of Sanitary Pads:

2.1 Soil Collection: Soil samples were collected from three distinct regions:

- A: Agricultural soil
- B: Garden soil
- C: Sewage soil.

These soils were selected to study the degradation of sanitary pads under different environmental conditions.

2.2 Degradation of Sanitary Pads in Soil:

Three sanitary pads were used for this experiment. The initial weight of the sanitary pads was measured before inoculating them into separate containers, each containing one of the three different types of soil (A, B, and C). After a specified incubation period, the pads were carefully removed from the soil, and the soil was cleaned off. The pads were then re-weighed to calculate the weight loss as an indicator of biodegradation. This method was also applied to shredded pads that were equal in weight to the intact pads. The biodegradation rate was calculated using the formula:

Degradation Rate = Initial Weight of Sanitary Pad – Final Weight of Sanitary Pad.

2.3 Incineration Process:

Prior to incineration, the sanitary pads were sterilized using UV light to eradicate all pathogens. Alternatively, the pads were immersed in a disinfectant solution (0.5% sodium hypochlorite or bleach) for 1–2 hours to ensure thorough disinfection. After soaking, the pads were washed with distilled water to remove any residual chemicals and were allowed to dry completely. The incineration process was conducted in a furnace maintained at temperatures ranging from 800°C to 1400°C, which were ideal for the combustion of substances present in sanitary pads, including cellulose, plastics, and superabsorbent polymers. The furnace was turned off once the combustion process was complete and was allowed to cool. Subsequently, the ash and remaining debris were removed, and plastic fragments were separated from the ash.

2.4 Chemical Method for Separation:

The procedure began by soaking the shredded sanitary pads in ethanol to dissolve the adhesives and separate the plastic layers from the rest of the material. The remaining components were then treated with an alkaline solution, such as sodium hydroxide (NaOH), which broke down the superabsorbent polymers while preserving the cellulose fibers. The cellulose was recovered through filtration, neutralized using a mild acid, and washed thoroughly with water. The recovered cellulose and plastic material were subsequently processed for potential recycling.

Table 2: Types of Degradation of Sanitary Napkins.

Type of Degradation	Description
Biodegradation	The breakdown of materials by microorganisms, such as bacteria and fungi, into simpler compounds.
Photodegradation	Decomposition of materials caused by exposure to sunlight, primarily UV rays.
Chemical Degradation	The breakdown of materials due to chemical reactions, such as oxidation or hydrolysis.
Thermal Degradation	The decomposition of materials under high temperatures, leading to a change in chemical structure.
Mechanical Degradation	The physical breakdown of materials due to mechanical forces like tearing, shredding, or abrasion.
Composting	A controlled process of biodegradation where organic materials are broken down into compost under aerobic conditions.
Enzymatic Degradation	The breakdown of materials facilitated by specific enzymes produced by microorganisms.

2] In-Vitro Degradation of Sanitary Pads:

2.1 Isolation of Microorganisms from Soil:

1g of soil sample was collected from a dump yard region with decaying food material and was mixed with 10 mL of saline. Eight sterile test tubes, each containing 9 mL of saline, were prepared. 1 mL of the soil sample was serially transferred to all the tubes. The samples were then inoculated onto Nutrient Agar and Cooked Meat Media (for bacterial growth) and Potato Dextrose Agar (for fungal growth). These plates were incubated at 37°C for 6-7 days. After incubation, bacterial isolates such as *Bacillus subtilis*, *Pseudomonas aeruginosa*, and *Clostridium titani*, as well as fungal isolates like *Aspergillus niger*, were obtained from Potato Dextrose Agar.

2.2 Identification of Bacterial Isolates:

Suspected bacterial colonies were inoculated into sterile nutrient broth or peptone water using a sterile loop and incubated for 2 hours at 37°C. Preliminary tests, including gram staining, motility, oxidase, and catalase, were performed to characterize the isolates. Further identification was conducted using biochemical tests.

2.3 Identification of Fungal Isolates:

The LPCB (Lactophenol Cotton Blue) wet mount technique was used to identify fungal isolates.

2.4 Microbial Identification Tests:

To confirm the presence of microorganisms capable of degrading sanitary napkins, several biochemical tests were performed (Table 3). These tests included the indole test, methyl red test, Voges-Proskauer test, citrate test, urease test, nitrate reduction test, phenylalanine deaminase test, and oxidative and fermentative tests.

Indole Test: The indole test was performed to determine whether microorganisms could convert tryptophan into indole. Indole production was identified by the appearance of a red colour after the addition of Kovac's reagent. If no colour change occurred, it indicated that tryptophan in the medium was not broken down, confirming the microorganism was indole-negative.

Methyl Red Test: The methyl red test was conducted to evaluate the ability of microorganisms to produce acid from glucose fermentation, leading to a reduction in the medium's pH. A red colour indicated a positive result, while yellow or orange suggested a negative outcome.

Voges-Proskauer Test: This test was used to check for the production of acetoin, an intermediate in the fermentation process. A positive result was indicated by the appearance of a red colour after the addition of reagents, confirming the presence of acetoin.

Citrate Test: The citrate test was carried out to assess whether microorganisms could utilize citrate as their primary source of carbon and energy. A positive result was shown by a colour change in the medium to blue, indicating the utilization of citrate.

Urease Test: The urease test aimed to detect the ability of microorganisms, such as *Aspergillus niger*, to hydrolyze urea into ammonia and carbon dioxide. A positive result was indicated by a pink colour due to an increase in pH from ammonia production, which altered the colour of the medium.

Nitrate Reduction Test: The nitrate reduction test was performed to evaluate the ability of microorganisms to reduce nitrate ions. A positive result was indicated by the development of a red colour after the addition of reagents, showing that nitrate had been reduced to nitrite or other nitrogen compounds.

Phenylalanine Deaminase Test: This test was conducted to determine whether the microorganism could produce the enzyme phenylalanine deaminase, which converts phenylalanine into phenylpyruvic acid. A positive result was confirmed by the appearance of a green colour after the addition of ferric chloride, aiding in the differentiation of Gram-negative bacteria.

Oxidase Test: The oxidase test was conducted to identify whether a bacterium produced the enzyme cytochrome c oxidase, which plays a vital role in the electron transport system during aerobic respiration. A positive result was indicated by a colour change to purple or blue on the test strip, confirming the presence of cytochrome c oxidase.

Fermentative Test: The fermentative test was carried out to determine the ability of bacteria to break down carbohydrates through fermentation. The production of acid or gas in fermentation tubes indicated a positive result, confirming carbohydrate fermentation.

Table 3: Result of Biochemical Test.

Test	<i>Bacillus subtilis</i>	<i>Pseudomonas aeruginosa</i>	<i>Clostridium titani</i>	<i>Aspergillus niger</i>
Indole Test	Negative	Negative	Positive	N/A
Methyl Red Test	Negative	Negative	Positive	N/A
Voges-Proskauer Test	Positive	Negative	Negative	N/A
Citrate Test	Positive	Positive	Negative	N/A
Urease Test	Negative	Negative	Negative	Positive
Nitrate Reduction Test	Positive	Positive	Positive	N/A
Phenylalanine Deaminase Test	Negative	Negative	Positive	N/A
Oxidase Test	Positive	Positive	Negative	N/A
Fermentative Test	Positive	Positive	Positive	N/A

2.5 Degradation of Sanitary Pads (In-vitro Conditions):

King's Medium B Base, Cooked Meat Medium, and Nutrient Broth were prepared for the bacterial isolates, while Potato Dextrose Broth was prepared for the fungal isolates. Shredded sanitary pads were added to the liquid media, and bacterial and fungal isolates were subsequently inoculated into the respective media. The tubes were incubated on a rotary shaker at a controlled temperature to ensure proper aeration and microbial activity. After the incubation period, the samples were processed and analyzed using Fourier-Transform Infrared (FTIR) spectroscopy to identify chemical bond changes and alterations in functional groups, providing insights into the degradation of the sanitary pads.

III. RESULTS

3.1 Analysis of FTIR Spectroscopy:

Fourier-transform infrared (FTIR) spectroscopy is a powerful analytical tool used to study the chemical composition and degradation of sanitary napkins treated with bacterial and fungal isolates. This method allows researchers to monitor changes in functional groups, providing insights into the breakdown of polymers and chemical bonds in the material. Below is an overview of how FTIR is applied in the context of biodegradation using bacteria and fungi.

Table 4: FTIR Analysis Table

Microbial Solution	Functional Group Region	Observed Changes	Interpretation
A: <i>Pseudomonas aeruginosa</i>	C-H Stretching (2800–3000 cm^{-1})	Decreased intensity	Indicates breakdown of hydrocarbons in the polymer structure.
	C=O Stretching (1650–1750 cm^{-1})	Reduction in carbonyl peak intensity	Cleavage of ester bonds in polymers.
	O-H Stretching (3200–3600 cm^{-1})	Broadening of peak	Suggests increased hydroxyl interactions due to enzymatic activity.
B: <i>Bacillus subtilis</i>	C-H Stretching (2800–3000 cm^{-1})	Significant reduction in peak intensity	Effective degradation of hydrocarbons.
	C-O Stretching (1000–1300 cm^{-1})	Changes in peak intensity	Attack on ester and ether bonds in cellulose or synthetic polymers.
	New Peaks (~600–800 cm^{-1})	Emergence of aromatic/cyclic byproduct signals	Formation of degradation intermediates such as aromatic compounds.
C: <i>Clostridium titani</i>	C-H and C=O Stretching	Reduction in both peak intensities	Anaerobic polymer degradation, involving ester bond cleavage.
	Lower Wavenumber Region (400–700 cm^{-1})	Shifts and new peaks	Interaction with metal ions or formation of secondary degradation products.
D: <i>Aspergillus niger</i>	O-H Stretching (3200–3600 cm^{-1})	Broadening and increase in peak intensity	Fungal enzymatic activity breaking down cellulose or lignin.
	C-O Stretching (1000–1300 cm^{-1})	Reduction in intensity	Degradation of polysaccharides like lignin or cellulose derivatives.
	New Peaks (1000–1500 cm^{-1})	Formation of intermediate alcohols, acids, etc.	Breakdown products from polymeric material degradation.

3.2 Analysis of Findings:

Efficiency of Degradation: The FTIR spectra demonstrate that all microorganisms evaluated play a crucial role in the breakdown of sanitary napkins, as indicated by the decrease in polymer-associated peaks (C-H, C=O, and C-O) and the emergence of new peaks signifying degradation byproducts.

Microbial Action:

- *Pseudomonas aeruginosa* and *Bacillus subtilis* demonstrate strong breakdown of hydrocarbons and esters, aligning with their capacity to generate enzymes such as lipases and cellulases.
- *Clostridium titani* operates efficiently in anaerobic environments, probably focusing on ester linkages and promoting metal attachment.
- *Aspergillus niger* shows significant activity on cellulose and lignin, decomposing these materials into simpler substances.

Metal Complexation and Byproduct Generation: Changes and new maximums in the lower wavenumber areas indicate metal complexation and the creation of breakdown byproducts. This underscores the possibility of microbes engaging with heavy metals throughout the degradation process.

Sustainability Factor: The microbial breakdown of sanitary napkins shown in this study is consistent with sustainable waste management objectives by transforming non-biodegradable polymers into eco-friendly substances.

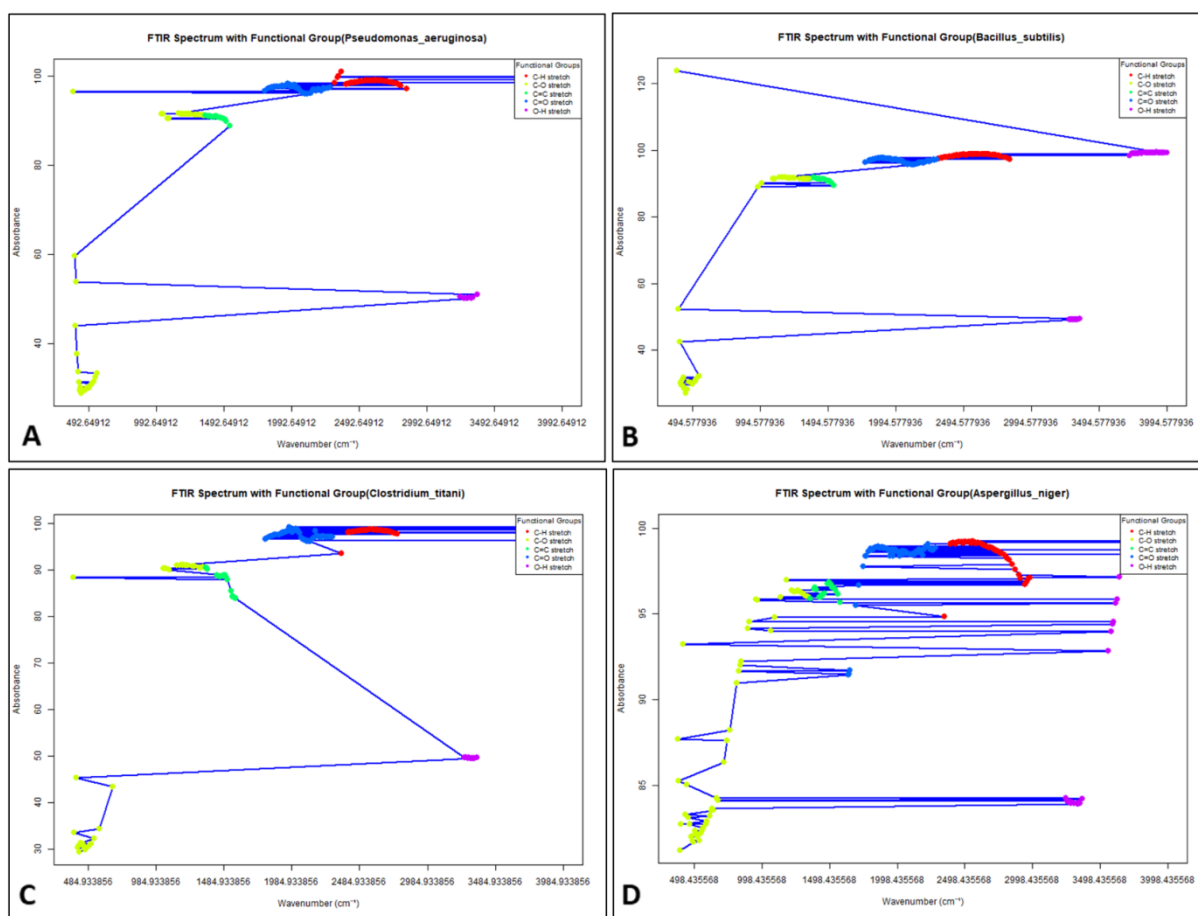


Fig.1: FTIR Spectra Graph (showing functional groups) of Selected Microorganisms. (a) *Pseudomonas aeruginosa*, (b) *Bacillus subtilis*, (c) *Clostridium titani*, (d) *Aspergillus niger*.

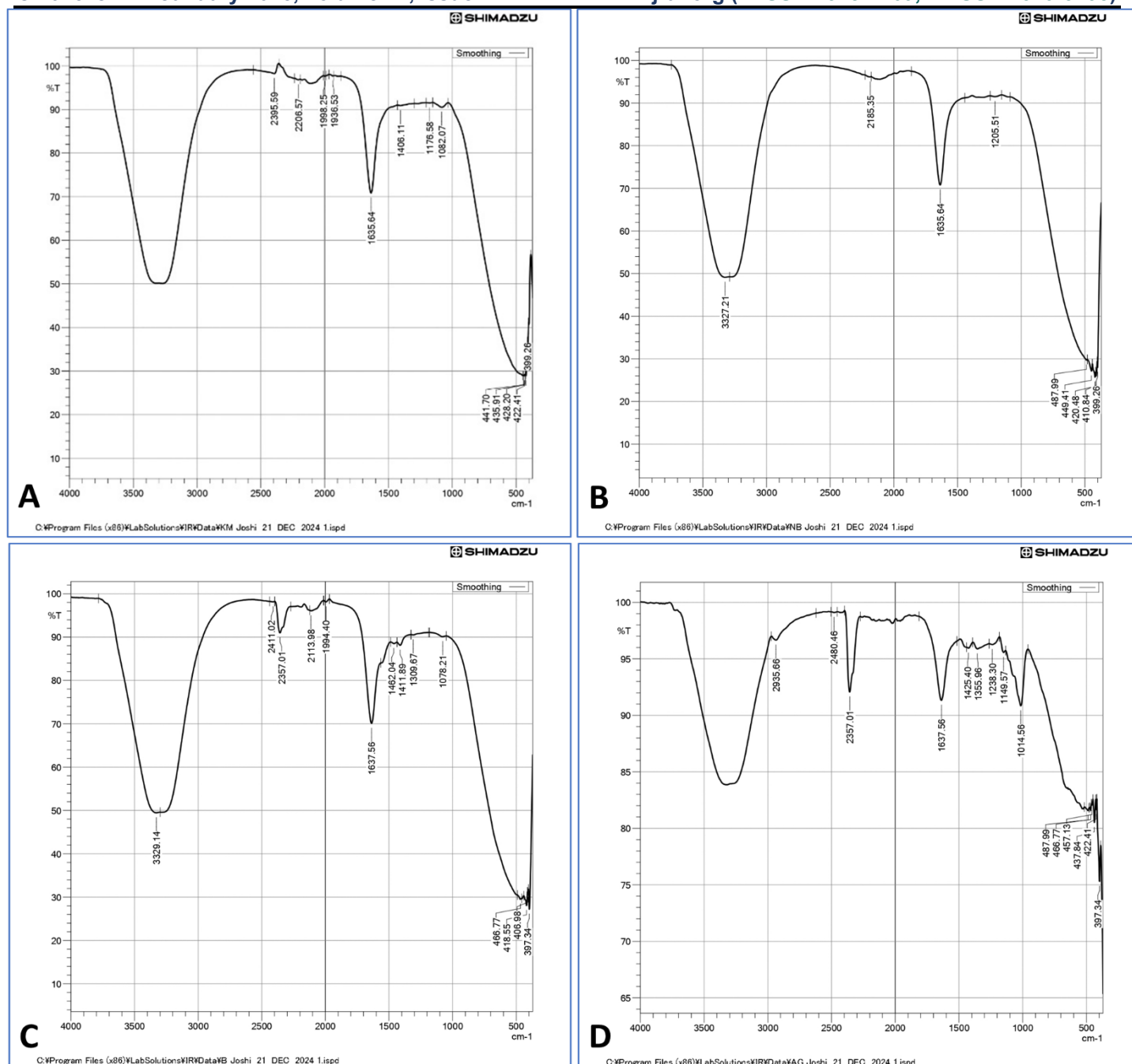


Fig.2: FTIR Analysis Report of Bacterial (a: *Pseudomonas aeruginosa*, b: *Bacillus subtilis*, c: *Clostridium titani*) and Fungal Isolates (d: *Aspergillus niger*)

IV. DISCUSSION AND CONCLUSION

Menstrual hygiene frequently requires sanitary napkins; however, their non-biodegradable materials and inadequate disposal present significant environmental issues. This research sought to explore the capability of microbes to break down sanitary napkins in natural in-vivo and regulated in-vitro settings. Microorganisms exhibiting enzymatic activity, such as species of *Bacillus*, *Pseudomonas*, and *Aspergillus*, were found to effectively break down natural fibers as well as synthetic polymers. The incorrect disposal of non-biodegradable sanitary waste was discovered to play a major role in environmental pollution and health issues. This study showed the effectiveness of using naturally occurring microorganisms, especially those present in soil, to decompose sanitary pads. Bacterial isolates like *Pseudomonas aeruginosa* and *Bacillus subtilis*, along with the fungal isolate *Aspergillus niger*, were effectively retrieved from soil samples taken at dumpsites. A comparative study of soil degradation under environmental conditions versus controlled laboratory (in-vitro) settings showed that in-vitro degradation produced superior outcomes. The identified fungal isolate *Aspergillus niger* and bacterial isolate *Pseudomonas* sp. emerged as the most effective degraders under in-vitro conditions, demonstrating greater enzymatic activity and degradation efficiency than soil-based methods. This showcased the considerable potential of utilizing controlled microbial breakdown for handling sanitary waste. The research determined that microorganisms, when used in a regulated setting, could efficiently break down both natural and synthetic substances present in sanitary pads. The results highlight the feasibility of microbial degradation as a sustainable and environmentally friendly method for minimizing sanitary napkin waste. By enhancing in-vitro conditions, this procedure could be advanced into a scalable approach for handling non-biodegradable sanitary waste on a broader scale.

V. FIGURES



Fig.3 Collection of sample



Fig.4 Weighing of sample



Fig.5



Fig.6 In-vivo degradation



Fig.7 Isolation of Fungi



Fig.8

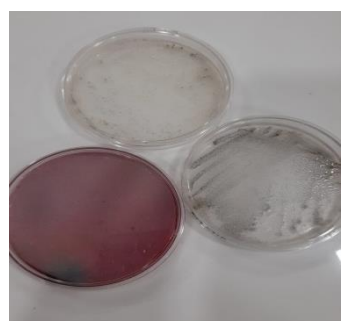
Fig.9 Biochemical tests
Degradation of sample

Fig.10 Sample inoculated in culture



Fig.11

VI. ACKNOWLEDGEMENT

We conveyed our sincere gratitude to Dr. Ashok Tejankar, Principal of Deogiri College and Mr. Mahadev. A. Jadhav, Head of Department of Biotechnology and Bioinformatics, Deogiri College, Chhatrapati Sambhajanagar for offering the necessary resources and facilities that supported our project "DEGRADATION OF SANITARY WASTE USING MICROORGANISMS". We expressed deep appreciation to our supervisor, Mrs. Devikirani P Pawar, for their exceptional guidance and unwavering support throughout the study. We also acknowledged the contributions and assistance provided by biotechnology department and our team members. Lastly, we were deeply grateful to our families and friends for their consistent encouragement and support during the research process. Lastly, we were deeply grateful to our families and friends for their consistent encouragement and support during the research process.

Ms. Sakshi R Gaikwad
Ms. Samruddhi P Joshi
Mr. Prince Kumar Ray

V. REFERENCES

- [1] G. McGuinness, et al., 2022: Menstruation in a Non-menstruator's World: Exploring the Relationship between Menstruation, Society and Space through the Experiences of People Who Menstruate.
- [2] A. Barman, P.M. Katkar, S.D. Asagekar, et al., 2018: Natural and sustainable raw materials for sanitary napkin Man Made Text. India, 46 (2018), p. 12.
- [3] M. Kirby, et al., 2017: Assessing Use, Exposure, and Health Impacts of a Water Filter and Improved Cookstove Distribution Programme in Rwanda, London School of Hygiene & Tropical Medicine (2017).
- [4] M. Dhinakaran, C.S. Senthil Kumar, T. Sathis Kumar et al., 2017: Development and characterization of sanitary napkin with lyocell/modal as absorbent core, IRJET, 4 (2017), pp. 1003-1006

[5] Anuradha, B. Pooja, M.K. and Asagekar, S. (2017). Development of eco friendly herbal finished sanitary napkin. International Journal for Innovative Research in Science & Technology 4(1), 183-189.

[6] Dhinakaran, M. Senthil kumar C.S. and Sathiskumar T. (2017). Development and characterization of sanitary napkins with lyocell / modal as absorbent core. International Research Journal of Engineering and Technology, 4(2),1003.

[7] P.M.S. O'Brien, et al., 2015: Disorders of menstruation, Shaw's Textbook of Gynaecology (sixteenth ed.), Elsevier, India (2015).

[8] J. Matos, C.I. Martins, R. Simoes, et al., 2024: Circularity micro-indicators for plastic packaging and their relation to circular economy principles and design tools Sustainability, 16 (5) (2024), p. 2182

[9] J. Elango, C. Zamora-Ledezma, J.E. Maté-Sánchez de Val, et al., 2023: Natural vs synthetic polymers: how do they communicate with cells for skin regeneration—a review, Journal of Composites Science, 7 (9) (2023), p. 385.

[10] Jihyun, B. Hoonjeong, K. and Jooyoun, K. (2018). Safety evaluation of absorbent hygiene pads: A review on assessment framework and test methods. Sustainability, 10(4146),1-17.

[11] E. Alzate, Y. Sánchez, et al., 2020: The use of sanitary pads and menstrual cups and their impact on environment, 2020 Congreso Internacional de Innovación y Tendencias en Ingeniería (CONIITI), IEEE (2020), pp. 1-5.

[12] J. Hand, C. Hwang, W. Vogel, C. Lopez, S. Hwang, et al., 2023: An exploration of market organic sanitary products for improving menstrual health and environmental impact, J. Water, Sanit. Hyg. Dev., 13 (2) (2023), pp. 63-77.

[13] I. Ghosh, D. Rakholia, K. Shah, D. Bhatt, M. Das, et al., 2020: Environmental perspective on menstrual hygiene management along with the movement towards biodegradability: a mini-review, 1 (5) (2020), pp. 122-126.

[14] J. Guo, Z. Zhang, J. Song, L. Jin, D. Yu, S. Liao, et al., 2022: Femvertising and postfeminist discourse: advertising to break menstrual Taboos in China, Wom. Stud. Commun., 45 (3) (2022), pp. 378-398.