

Indigo Frost: Sustainable Ice-Assisted Dyeing for Kids wear

Minal J¹, Asmitha J², Murshina S³, Gnana Vijila M⁴, Arorose Apciniya M⁵

^{1,2,3,4} B.Sc.student, Department of Costume Design and Fashion Holy Cross College[Autonomous],
Nagercoil – 629 004

⁵ Assistant Professor⁵, Department of Costume Design and Fashion Holy Cross College[Autonomous],
Nagercoil – 629 004

Abstract—Indigo is one of the oldest natural dyes and is mainly obtained from the *Indigofera tinctoria* plant. It is widely used in textiles because of its attractive blue colour and traditional value. This project focuses on using indigo dye with an ice-cube dyeing technique to create unique colour effects on children's wear. Indigo dyeing is considered a more sustainable option compared with many synthetic dyes, which may cause environmental pollution and health problems.[15] The ice-cube technique helps to produce interesting patterns and different shades on fabric by allowing the dye to spread slowly as the ice melts. Natural indigo is also biodegradable and can support eco-friendly textile production when properly processed. Children's clothing requires special attention to safety, comfort, and skin-friendly materials. Therefore, combining natural indigo dyeing with creative ice-dyeing techniques can provide attractive and environmentally conscious designs for children's garments. This project explores the potential of this method for developing sustainable and visually appealing kid's wear.[2]

Index Terms—Antioxidant properties, Bio modrants, Childrens wear, Colour effects, Eco-friendly dyeing, Ice-cube dyeing, Indigo dye, Natural mordants, Sustainable textiles.

I. INTRODUCTION

Plastics, synthetic dyes, and other industrial materials have become an important part of modern life. Plastics are widely used because they are lightweight, convenient, durable, and inexpensive. They are commonly found in packaging, food containers, furniture, toys, bags, and many other products. However, the excessive use of single-use plastics has created serious environmental problems because plastic takes a very long time to break down. Large

amounts of plastic waste enter landfills, oceans, and other natural environments, causing pollution and affecting biodiversity. Therefore, there is a growing need to develop biodegradable and eco-friendly alternatives.[13]

Agricultural waste is another major environmental concern. Waste materials such as plant residues and other lignocellulosic materials are produced in large quantities. One promising approach is the development of biodegradable materials and mycelium-based composites. These materials use agricultural waste as a growing substrate for fungi. The fungal mycelium acts as a natural binder, joining the waste particles together. Mycelium-based materials are lightweight, biodegradable, have a low environmental impact, and can be used in packaging, furniture, construction, and other applications. Textile dyeing is also an important environmental issue. Natural dyes have been used for centuries and are obtained from sources such as plants, insects, lichens, and other natural materials. Indigo is one of the oldest and most popular natural dyes, especially known for its deep blue colour. This project focuses on the importance of sustainable materials and eco-friendly textile practices. It highlights the use of biodegradable materials, agricultural waste, natural dyes, and improved dyeing methods. By reducing plastic waste, reusing agricultural residues, and encouraging natural dyeing, sustainable production can help protect the environment while supporting innovative and responsible textile and fashion development.[16]

II. MATERIALS AND METHODS

2.1 Indigo Plants and Sources of Essential

Indigo is one of the oldest natural dyes used for colouring textiles. It is obtained from different plants that contain indigo-producing compounds. One important species is *Polygonum tinctorium* Ait., which belongs to the Polygonaceae family and is mainly found in regions of China and India. It can grow up to about 80 cm and has reddish stems, narrow leaves and attractive pink or red flowers. Another important indigo-producing plant is *Baphicacanthus cusia*, a perennial plant that grows well in moist and clayey soils. It can tolerate different soil conditions and grows in both partial and full shade. *Isatis indigotica*, commonly known as woad, is another source of indigo and is found in parts of Europe and Asia.[11]

The extraction of indigo traditionally involves harvesting the leaves and allowing them to undergo soaking, fermentation or composting. Warm and

humid conditions can help in the breakdown of plant material and support the extraction of indigo compounds. The extracted dye can then be used for colouring textile materials. Dyes are substances used to add colour to textiles, paper, leather and other materials. Natural dyes are especially valuable in sustainable textile production because they can be obtained from renewable sources. The colour of a dye is produced by chemical groups called chromophores, while auxochromes can help increase or modify the colour. Eco-design focuses on selecting materials and production methods that have less impact on the environment. Natural fibres such as cotton, flax, hemp, mulberry and ramie are commonly used in sustainable fashion. They are biodegradable and can provide useful properties such as breathability, moisture absorption and comfort. Therefore, combining natural fibres with natural dyes such as indigo can support environmentally responsible and sustainable textile development.[10]

I. COMMON SOURCES INCLUDE

Table 1. Common Sources of Essential

Dye	1] Henna Scientific Name: <i>Lawsonia inermis</i>	
	2] Indigo Scientific Name: <i>Indigofera tinctoria</i>	
	3] Madder Scientific Name: <i>Rubia tinctorum</i>	

	4] Neem Scientific Name: <i>azadirachta indica</i>	
--	--	--

The use of natural indigo plants as dye sources supports sustainable textile production, promotes the use of renewable resources, and helps reduce the environmental impact associated with synthetic dyes.

selection, and environmentally friendly methods in developing sustainable textile products.[12,13]

III. EXTRACTION PROCESS

2.2 Preparation of Raw Materials

This project focuses on the use of natural indigo dye and ice cubes in an eco-friendly textile process. Indigo is a traditional natural dye obtained from plants such as *Polygonum tinctorium*, *Baphicacanthus cusia*, and *Isatis indigotica*. The project explores the preparation of raw materials, dye extraction, and application of indigo on cotton fabric. Ice cubes are used as a simple cooling material during the experimental process and can help control temperature when required. The project promotes sustainable textile practices by using natural resources and reducing dependence on harmful synthetic chemicals. Overall, this work highlights the importance of natural dyes, responsible material

Fresh indigo leaves are collected, cleaned, soaked, fermented, and aerated to obtain the natural blue colour pigment. The extracted indigo dye is then applied to cotton fabric to produce different shades and effects. Ice cubes are used during the dyeing process to create irregular colour patterns, lighter areas, and a unique vintage appearance. Ice cubes are introduced during the dyeing process to create unique, irregular colour patterns and a vintage or faded effect. The use of natural indigo helps reduce dependence on harmful synthetic dyes and supports environmentally friendly textile practices. This project also demonstrates a simple and creative dyeing technique that can be used to develop attractive and sustainable textile designs.[8]

II. COMMON EXTRACTION METHODS

Table 2. Common extraction methods of Natural Indigo Dye

S.No	Extracte process	Descript
1.	Aqueous extraction	Use water to extract natural indigo from leaves; eco-friendly and suitable for cotton / muslin cotton fabric dyeing.[7]
2.	Aeration method	Introduces oxygen into the extracted solution to promote the formation of the blue indigo pigment.[13]
3.	Ice-cube dyeing method	Ice cubes are placed on dyed or dye-treated fabric to create irregular, faded and attractive colour patterns.[16]
4.	Soaking or maceration	Simple and low-cost method of soaking indigo leaves in water before further processing.[9]

After extraction, the solution is filtered to remove solid leaf residues, yielding a clean natural indigo extract suitable for fabric dyeing and ice-cube dyeing effects.

IV. CONCENTRATION AND STABILIZATION

After extraction and filtration, the indigo dye extract is concentrated by reducing excess water to obtain a stronger colour solution. The extract is then stabilized by maintaining suitable conditions such as proper pH and storage away from direct sunlight. This helps maintain the colour quality and improves its suitability for cotton fabric dyeing. For the ice-cube technique, the prepared indigo dye is applied to the fabric, and ice cubes are used to create uneven, soft, and vintage-style colour effects.[5]

V. INFUSION /APPLICATION METHODS

Indigo is extracted from indigo leaves through soaking, fermentation, and aeration, followed by filtration to obtain the dye extract. The dye is applied to soft cotton fabric using dip dyeing or direct application methods. Ice cubes are used during the application process to create soft, irregular, and attractive patterns with a unique vintage effect. The finished fabric is gently washed to remove excess dye and improve comfort. This project promotes sustainable textile practices while creating comfortable, colourful, and child-friendly kids wear designs.[16]

VI. DRYING AND CURING

After the natural indigo dyeing and ice-cube application process, the cotton fabric is carefully prepared for drying and curing. First, excess dye and water are gently removed from the fabric without rubbing or squeezing it harshly. This helps to preserve the unique patterns and colour variations produced by the ice-cube technique. The dyed fabric is then spread evenly in a clean and well-ventilated area and allowed to dry naturally. Shade drying is preferred because strong direct sunlight may cause the natural indigo colour to fade.[3]

Once the fabric is sufficiently dry, it is allowed to cure for a suitable period. Curing helps the colour to develop and settle properly on the cotton fibres. After curing, the fabric is gently washed with clean water or a mild detergent to remove excess and unfixed dye. It is then rinsed thoroughly and dried again in the shade. Finally, the fabric can be lightly ironed at a suitable temperature to improve its appearance and remove

wrinkles. Proper drying and curing help maintain the blue colour, soft handle, attractive irregular patterns, and overall quality of the fabric. This process is important for producing comfortable, visually appealing, and eco-friendly kids wear using natural indigo dye and the ice-cube technique.[8]

VII. ADVANTAGES OF EXTRACT INFUSION

Indigo[Natural] extraction and infusion offer several advantages for developing eco-friendly kids wear. The use of natural indigo provides an alternative to synthetic colourants and supports sustainable textile production. Water-based extraction is simple, economical, and requires easily available materials. Indigo produces attractive blue shades that can enhance the visual appeal of children's garments. The ice-cube application technique creates unique, irregular, soft, and artistic patterns without requiring complicated equipment.[15] It also allows different colour effects to be developed by changing the amount of dye, ice placement, folding, or fabric arrangement. Natural dyeing can provide a pleasant appearance and comfortable feel when suitable cotton fabric and proper processing methods are used. The process can also encourage the use of traditional dyeing knowledge along with modern creative techniques. It reduces dependence on petroleum-based synthetic dyes and promotes environmentally responsible practices. Overall, combining natural indigo extraction with ice-cube dyeing provides a creative, simple, sustainable, and visually attractive method for designing comfortable kids wear.[20]

7.1 Eco-Friendly and Biodegradable

Natural indigo dyeing is an eco-friendly and biodegradable approach that can be used to develop sustainable kids wear. Indigo obtained from natural plant sources is renewable and can reduce the dependence on synthetic dyes made from petroleum-based chemicals. The use of water-based extraction also makes the process simple and more environmentally responsible. Natural dyeing can help reduce the release of certain harmful chemical substances into the environment when compared with conventional synthetic dyeing, although proper wastewater treatment is still important. Cotton fabric, commonly used for kids wear, is also biodegradable under suitable natural conditions. The ice-cube dyeing

technique adds creative patterns without requiring complicated machinery or additional synthetic printing materials. Using natural materials and simple dyeing methods can support waste reduction and responsible textile production. The final fabric can provide a soft and attractive appearance suitable for children's clothing. Overall, natural indigo combined with ice-cube dyeing promotes eco-conscious fashion, renewable resources, biodegradability, and sustainable textile practices, making it a useful approach for environmentally friendly kids wear development.[6]

7.2 Reduced Reliance on Synthetic Chemicals

Using natural indigo dye helps reduce the dependence on synthetic chemicals commonly used in textile colouring. Natural indigo is obtained from plant sources and can provide attractive blue shades without relying mainly on petroleum-based synthetic colourants. In this project, a simple water-based extraction method is used, which reduces the need for strong chemical solvents. The ice-cube technique also creates interesting patterns without requiring additional chemical printing agents. This makes the dyeing process more environmentally responsible and suitable for developing sustainable kids wear. By choosing natural dyeing methods, the project encourages the use of renewable resources and supports cleaner textile production while reducing the overall use of synthetic chemicals.[18]

7.3 Multifunctional Performance

Natural indigo dyeing can provide more than just colour to textile materials. In this project, indigo is used to create attractive blue shades and unique patterns on cotton fabric for kids wear. The ice-cube technique adds a creative visual effect by producing uneven and artistic colour patterns. Natural indigo may also offer useful properties such as good colour depth and a distinctive appearance when properly applied and finished. The cotton fabric provides softness, comfort, and breathability, which are important for children's clothing. By combining natural dyeing, creative surface effects, and comfortable fabric, the project provides both aesthetic and functional value. This makes the finished kids wear more attractive, comfortable, and environmentally conscious.[12]

7.4 Skin Safety and Environmental Sustainability

This dye can support both skin-conscious clothing and environmental sustainability when it is properly processed and tested. For kids wear, soft cotton fabric is preferred because it is comfortable, breathable, and gentle for regular wear. Using a water-based extraction method can reduce the need for strong chemical solvents. The ice-cube dyeing technique creates attractive patterns without requiring additional synthetic printing materials. Proper washing of the dyed fabric is important to remove unfixed dye and reduce the possibility of skin irritation. The dyeing wastewater should also be handled responsibly to avoid environmental pollution. Overall, the project combines natural materials, simple processing, comfortable fabric, and creative dyeing techniques to promote safer and more sustainable kids wear.[16]

VIII. APPLICATIONS OF EXTRACT-INFUSED MATERIALS

Extract-infused materials can be used in different textile applications by adding natural colour and functional value to fabrics. In this project, natural indigo extract is applied to cotton fabric to develop attractive blue shades for kids wear. The ice-cube technique is used to create unique, irregular, and artistic patterns on the fabric. These materials can be used for children's dresses, tops, skirts, shorts, scarves, and other fashion accessories. Natural indigo can also be applied in craft products, home textiles, and decorative fabric items. The technique is simple and suitable for small-scale textile production. Overall, extract-infused materials provide opportunities for creative design, sustainable fashion, and eco-friendly textile development.[14]

8.1 Sustainable Indigo Dyeing

Sustainable indigo dyeing is an eco-friendly approach to colouring textiles using natural indigo obtained from plant sources. In this project, natural indigo is applied to cotton fabric to develop attractive blue shades suitable for kids wear. A simple water-based extraction process helps reduce the use of strong chemical solvents. The ice-cube dyeing technique is used to create unique, irregular, and artistic patterns on the fabric. This method encourages the use of renewable natural resources and reduces dependence on synthetic colourants. Proper washing and

wastewater management are also important for reducing environmental impact. Overall, sustainable indigo dyeing combines natural materials, creative design, and responsible textile practices to produce attractive and eco-friendly kids wear.[17]

8.2 Indigo Kids Wear Textiles

Indigo can be used to create attractive and eco-friendly textiles for children's clothing. Cotton fabric dyed with indigo provides beautiful blue shades and a natural appearance. The ice-cube dyeing technique adds unique, irregular patterns, making each garment creative and different. These textiles can be used for kids' dresses, tops, skirts, shorts, and other casual garments. The combination of natural indigo, cotton fabric, and ice-cube effects supports sustainable and creative kids wear design.[18]

8.3 Indigo Kids Wear Applications

This dye can be applied to different types of kids wear to create attractive, comfortable, and eco-friendly garments. In this project, indigo dye is used on cotton fabric to produce different shades of blue. The ice-cube dyeing technique adds unique and irregular patterns, giving each fabric a creative appearance. The dyed material can be used for children's dresses, tops, skirts, shorts, frocks, and casual wear. Cotton is preferred because it is soft, breathable, and comfortable for children. The technique can also be used for small accessories such as headbands, scarves, and fabric bags. Overall, indigo dyeing provides a simple and creative way to develop sustainable and attractive kids wear.[7]

8.4 Wellness and Lifestyle

Indigo dyeing [Natural] can be connected with a sustainable and eco-conscious lifestyle through the use of natural materials and environmentally responsible textile practices. In this project, natural indigo is used to colour cotton fabric for kids wear, while the ice-cube technique creates simple and attractive patterns. Choosing naturally dyed clothing can encourage awareness of sustainable fashion and responsible consumption. Cotton fabric also provides softness, comfort, and breathability, making it suitable for everyday children's wear. The project promotes the idea of choosing durable, comfortable, and environmentally friendly textile products. Overall, natural indigo kids wear combines comfort, creativity,

sustainability, and mindful lifestyle choices, making it a suitable option for eco-conscious fashion.[10-11]

IX. CONCLUSION

This project successfully explores the use of natural indigo dye and the ice-cube dyeing technique for developing sustainable kids wear. Natural indigo obtained from plant sources provides attractive blue shades and offers an eco-friendly alternative to conventional synthetic dyes. The simple extraction process using water helps reduce the dependence on strong chemical solvents and supports sustainable textile practices.

The ice-cube technique adds a creative element to the dyeing process by producing irregular, soft, and unique colour patterns. Each fabric can have a slightly different appearance, making the finished kids wear more interesting and attractive. Cotton fabric is suitable for this project because it is soft, breathable, and comfortable for children. Proper filtration, drying, curing, and washing are important to improve the appearance and quality of the dyed fabric.[2] The project also highlights the importance of responsible wastewater management to reduce environmental impact.

Overall, combining natural indigo with ice-cube dyeing provides a simple, creative, and sustainable method for designing kids wear. It encourages the use of natural resources, reduces reliance on synthetic colourants, and promotes environmentally conscious fashion. The project demonstrates that sustainable dyeing can be both practical and visually appealing for modern children's clothing.[1]

AKNOWLEDGMENT

All the authors have equally contributed in writing this article.

Minal, Asmitha, Murshina, Vijila have assisted in literature collection, data organization, and initial and final drafting of the review.

Arorose Apciniya has provided guidance on review framework, critically revised the manuscript, and approved the final version.

REFERENCE

- [1] Steingruber E.: Indigo and Indigo Colorants. Ullmann's Encyclopedia of Industrial Chemistry, John Wiley & Sons, New Jersey 2004.
- [2] Splitstoser, J.C., Dillehay, T.D., Wouters, J. & Claro, A. Early pre-Hispanic use of indigo blue in Peru. *Sci. Adv.* 2, e1501623 (2016).
- [3] Erdawati et al 2023 IOP Conf. Ser.: Earth Environ. Sci. 1187 012014
- [4] Zollinger H. Synthesis, Properties of Organic Dyes and Pigments. In: Color Chemistry.: VCH Publishers (New York, USA. 1987, p. 92-102).
- [5] De, S.K., and Palit, S.R., Isolation of Benzene-Soluble Dye-Bases by Freeze-Drying Technique, *Sci. Culture* 32 (11), 553-554 (1966).
- [6] Aiduang, W., Chanthaluck, A., Kumla, J., Jatuwong, K., Srinuanpan, S., Waroonkun, T., ... & Suwannarach, N. (2022). Amazing fungi for eco-friendly composite materials: A comprehensive review. *Journal of fungi*, 8(8), 842.
- [7] Pizzicato, B., Pacifico, S., Cayuela, D., Mijas, G., & Riba-Moliner, M. (2023). Advancements in sustainable natural dyes for textile applications: A review. *Molecules*, 28(16), 5954.
- [8] Joyce, A. (2019). *Hand dyed: a modern guide to dyeing in brilliant color for you and your home.* Abrams.
- [9] Santiago, D., Mehravani, B., Alves, C., Cabral, I., Cunha, J., Zille, A., & Padrão, J. (2025). Antibacterial and Antioxidant Performance of Natural Textile Dyes for Children's Wear. *Applied Sciences*, 16(1), 307.
- [10] Ahmed, O. K., & Elsayed, N. A. (2019). Fabric manipulation as a fashion inspiration source for children clothes. *International Design Journal*, 9(4), 79-91.
- [11] Sanjeevana, D., & Thenmozhi, R. (2022). Study on product safety of children's apparel. In *Sustainable Approaches in Textiles and Fashion: Manufacturing Processes and Chemicals* (pp. 157-169). Singapore: Springer Singapore.
- [12] Yang, Y., Ladisch, C. M., & Ladisch, M. R. (1990). Freeze concentration of dyes. *Textile Research Journal*, 60(12), 744-752.
- [13] Shan, B., Xiong, W., & Zhang, S. (2019). Dyeing method and properties of a novel blue azo-anthraquinone reactive dye on cotton. *Molecules*, 24(7), 1334.
- [14] Zhang, C. (2025). *Immersive Indigo Exhibition: Exploring Traditional Indigo Through Play and Making* (Master's thesis, Pratt Institute).
- [15] Nanthagopal, N., & Jothilinkam, M. D. (2018). A study of natural dyeing in sustainable product development. In *Sustainability in Fashion and Apparels* (pp. 22-31). WPI Publishing.
- [16] Mocquard, J., Le Lamer, A. C., Fabre, P. L., Mathieu, C., Chastrette, C., Vitrai, A., & Vandenbossche, V. (2022). Indigo dyeing from *Isatis tinctoria* L.: From medieval to modern use. *Dyes and pigments*, 207, 110675.
- [17] Jilil, M. H., & Shaari, N. (2023). Sustainable kids fashion: Designers' viewpoint toward multifunctional children's wear design. *Int. J. Sustain. Trop. Des. Res. Pract*, 16, 2-11.
- [18] Prabhakar, D., & Rajagopal, S. (2022). Exploration of kids ready to wear clothing brands for measurement and fit discrepancies. *Research Journal of Textile and Apparel*, 26(1), 57-72.
- [19] Lii, H. C., & Huang, J. W. (2025). Analysis and optimization strategies for key factors in children's clothing design. *Fashion, Style & Popular Culture*.
- [20] Rita, A. A. (2018). Specific requirement for development in children's clothing: customer's preference and satisfaction for buying. *International Journal of Business Marketing and Management*, 3(8), 20-29.