

Role of colour in ecological approach to product and material design

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ABSTRACT: The aim of this research paper is to map, document and classify new, progressive and perspective approaches to colour in product and material design. The purpose is to identify the impact and importance of colour in the creation of new materials and products from an ecological point of view. The majority of current progressive approaches to design creation and research is set in an ecological framework, taking into account their impact on the environment. The question is not whether colour is present in this process, but rather where it stands in this process, whether it can help it and how much it affects it. One of the objectives of this article is to raise awareness in this area and to arouse interest in and discussion on this topic. The theme of colours in design is often overlooked and relegated to the background. The results of several scientific studies on the impact of colour on product evaluation and consumer shopping behaviour suggest the potential of this topic and open up space for further research. In this research paper, we consider the approach of product and material designers and researchers to colour in an ecological context, as a stand-alone design and material creation group. Within this main group, individual approaches can be classified into four basic principles, which the paper defines and describes. They are analysed and researched in more depth through specific examples of the work of various designers. The principles have no fixed boundaries, they are not isolated. They influence or follow each other. This classification of the approach to colour in an ecological context allows us primarily to talk about it more professionally and attempt to define its importance and role in individual approach. Ultimately, it helps us answer the question of whether and how colour can affect the process of changing human interaction with the environment.

KEYWORDS:

colour, design, ecology, circular economy, recycling, sustainability, bio-based material

INTRODUCTION

The majority of current progressive approaches to creation and research is set in an ecological framework, taking into account their impact on the environment. This approach is also defined in the *Declaration of Design* (Montreal, 2017), where one of the basic pillars is, when designing new products, the challenge to take into account their environmental impact, while recognizing the importance of design in shaping the world: *"The role of design to create a world that is environmentally sustainable, economically viable, socially equitable, and culturally diverse is fundamental and critical."* [1]

Before examining the role of colour in the ecological approach to product design, it is necessary to answer a few questions - What is the role of designers today and what are their obligations and responsibilities in design? What position do they have in the process of creating new redundant products? In addition, the ethical aspect of this kind of design creation must be reviewed. The new generation of designers responds to the

change from linear to circular economy; using their creative skills, they seek to positively influence the changes that are currently taking place in the society. This approach to current design creation is also captured in the emerging New European Bauhaus movement, which is: *"... environmental, economic and cultural initiative, combining design, sustainability, accessibility, affordability and investment to help implement the European Green Agreement."* [2]

The question is not whether colour – as an inseparable attribute of design – is present in this process, but rather where it stands in this process, whether it can help it and how much it affects it. This is also an initial outline of the main research question of this article.

Importance of colour

In a study conducted by Satyendra Singh of the University of Winnipeg, published in 2006, the importance of colours in creating new products is reflected: *"People make up their minds*

within 90 seconds of their initial interactions with products. About 62-90 percent of the assessment is based on colours alone." Also, according to the study: "84.7% of consumers state that colour is the main reason that they buy specific products." [3] This means that colour in design cannot only be an artistic aspect conditioned by the artistic feeling of the creator, but rather represents a very important tool influencing the consumer's perception and the success of the product on the market. Therefore, the approach to colour application to the products and materials should be responsible and conceptual. Failure to employ the potential of colours in shaping new circular and ecological approach would be a missed opportunity.

MOTIVES AND METHODS

The aim of this article is to explore and examine the role of colours in the ecological approach to design, in order to raise awareness in this area and arouse interest in and discussion on this topic. Various questions need to be answered – starting with how contemporary designers work with colour in the ecological context, through researching how colours can help to close the circle of circular economy, ending with the question if and how it is possible to classify various ecological approaches to circular design from a colour point of view.

This article has mainly scientific character and each topic and question addressed in it has potential for more detailed objective studies. It can be considered the initial piece of a mosaic that needs to be composed around this subject, with further collaboration of other material designers, scientists, chemists, sociologists, and environmental engineers.

The first step is to analyse the problematic parts of the subject and to recognize opportunities for improvement. The next step is to identify and classify different designer approaches, material researchers and scientists to this topic using the comparative method. The primary reason of the classification is to define the position of colour in the circular design process, draw attention to the topic, and facilitate the discussion about it.

To understand and capture the importance of colour in circular design, various studies, papers and articles were reviewed. Besides that, many works of professional as well as aspiring designers were considered. There are also a few emerging organizations that try to capture and harness current ecological colour trends in material design e.g.: *Colour of saying* – an experience-driven CMF design agency empowering brands and organisations to harness colour and materials as agents of change [4], *Surface matter* – a leading authority on material innovation and application and its purpose is to discover the latest materials and introduce them to people [5], *Radical Colour* – a platform on Medium [6] that offers an intelligent perspective on colour through series of interviews and articles [7].

The motivation of this article includes helping us to create a snapshot of where the colour is in contemporary design creation against the backdrop of ecology and where it is heading. And to see the importance and impact of colour in the process of the much-needed change in the attitude of the society to-

wards environment. Ultimately, to inspire and motivate more designers to use colour boldly, but wisely and conceptually.



Figure 1: Material moodboard showing material samples of sustainable materials from different companies and designers.

© Surface Matter

Source: <https://www.surfacematter.co.uk>

PROBLEMS AND OPPORTUNITIES OF THIS TOPIC

When examining more specific research questions, three main problems have been identified:

1. Research gap

To the best of our knowledge, and based on the lack of professional and popular studies and papers, the potential of colour in the context of sustainability is not currently being researched sufficiently and limited research has been devoted to this topic. One of the problems identified when approaching the topic is that it is often overlooked and relegated to the background. The results of research on the impact of colour on product evaluation and consumer shopping behaviour, cited also in this paper, suggest the potential of this subject and open up space for further research.

The reasons why colour does not yet have an important place in conversations about sustainability was outlined by Dan Dick-er, circular design pioneer and founder of Circular&Co, in his interview for *Radical Colour* platform on Medium [6]: "Perhaps colour is considered too frivolous to take part in these serious conversations, too difficult or too contentious. Whatever the reason, we can no longer ignore colour's ubiquity in linear take-make-waste systems. (...) it is also the impossibility of achieving circularity without considering how we make, apply and reincorporate colour." [8]

2. Manufacturers and colour

Another problem that appears, when approaching this topic, is to understand and overcome how manufacturers and corporations have bent our perception of colour in recent years, in order to increase the sales and consumer lifestyle.

The best demonstration of this statement is the notion of blue and pink colour, where the first one is strictly associated with boys and the other one with girls. Various studies conducted on this topic indicate that there is no scientific or historic background to associate blue and pink colours with a gender [9]. From historical sources, we can observe that in the 19th century, both colours were used equally for boys and girls and the most used colour for babies, for practical reasons, was white [10]. The colour coding as we know it today did not exist and pink and blue were not a sign of gender, but simply the sign of wealth of the upper class: *"It wasn't until after WWII when pink for girls and blue for boys took hold,"* says Dr Erin Stapleton, an Honorary Fellow at the School of Historical and Philosophical Studies [11]. In western countries, it was a boom time for mass production, mass consumption and baby-making: *"Manufacturers pushed the fad too after realizing affluent parents would buy a whole new set of baby products once they found out Junior was expecting a little sister."* [10]

There are more examples similar to the one mentioned above confirming that our perception of colours has been distorted for a long time, just to buy more and enhance the consumer style of life. Our expectation of the properties of colours is also affected. We want colours to be bright and stable, to look the same under all lighting conditions and there is no room even for a slight fading or changing of the colour shade. It is also time to question the persistence of colour, which today is designed to last much longer than the product itself. This approach leads to the use of synthetic and chemically enhanced colours, which on one side have the "right" properties; on the other side, it makes these colours non-ecological, hard to recycle and flat. According to Laura Perryman from the Radical Colour platform: *"In a circular economy, where the planet is our ultimate customer and client, we must take colour decisions seriously and consider if the aesthetic and functional enhancements colour brings to a material justify the environmental costs."* [12]

Another opinion worth considering when discussing the necessity of long-lasting colours that will not fade is formulated by Dan Dicker, mentioned before in this article: *"In terms of longevity, the classic example is jeans: the older they get, the more worn they get, the better they look. So, there is a market or a movement where people relish that. If you can get that feeling with other products..."* [8] This claim might imply that if there is room to accept the colour changes in some products and even to consider them a positive feature, it takes only changing the consumer point of view to accept this feature in other products.

3. Colour relativity

When considering the stability of colour, there is another obstacle that many manufacturers attempt to overcome. One of the basic characteristics of colour is its relativity: *"If one says 'Red' (the name of the colour) and there are 50 people listening, it can be expected that there will be 50 reds in their minds. And one can be sure that all these reds will be different,"* wrote Josef Albers in his book *Interaction of Colour*, today considered a masterwork in art education [13]: *"... Colour is the most relative medium..."* In his book, Albers shows on many practical

exercises, how colours and their perception easily change and that colour is never perceived alone: *"Colours present themselves in continuous flux, constantly related to changing neighbours and changing conditions."*

There are many variables that come into account when observing colour: another colours, light circumstances, environment, concept, context, culture, etc. Nevertheless, manufacturers have tried to stabilize colours for a long time and want them to look the same in all these circumstances. Besides, there is a popular concept of branded colours, when corporations have their signature colours anchored deep inside in their design manuals, not allowing even a slight change in the shade when used for promotional products.

But we can see an effort of some designers who are trying to rebel against the flatness of the colour industry, such as Hella Jongerius, a Dutch designer, who devoted almost all her design work to pushing the boundaries of this industry: *"Thousands of colours of paint are manufactured, and all those colours are designed to look just the same under all conditions, regardless of the light source. We have sacrificed the quality of colours that show irregularities and thus provide a richer experience."* [14] Jongerius believes that in recent decades, the paint industry has focused too exclusively on standardization and quantity. She never followed business and modern colour trends; instead, she developed the use of colours that are characteristic of her own. In her exhibition entitled *Breathing Colour* (Design Museum London, 2017), she highlighted her vision of colours that she formed into giant objects – Colour Catchers. They were designed to capture colour from many perspectives which achieve a multitude of gradients throughout the three-dimensional forms, pointing out to the relativity of perceived colour. [15]

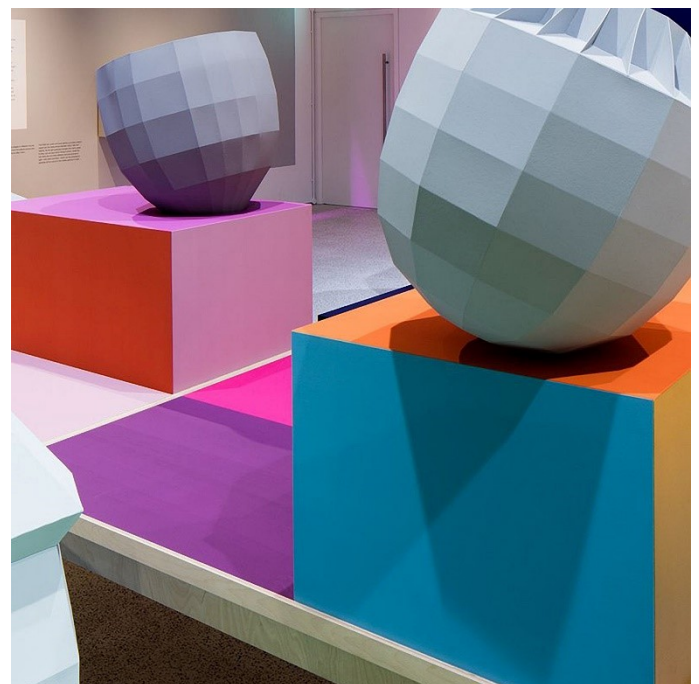


Figure 2: Breathing Colours – Colour Catchers.

© Luke Hayes

Source: <http://www.jongeriuslab.com/work/breathing-colour-the-colour-catchers>

Even though ecology was not the main topic in Jongerius's work, the attitude she promoted in her various works – where the business trends and colour standards are left behind – may not only be the way to open us the real variety and richness of colours, but also the way to a more sustainable approach to them.

PRODUCT COLOURING

To understand better the function of colour in the designing and manufacturing process, it is necessary to mention the colouring process itself, which defines how colours get on the material or product and where they are present.

From this point of view, we distinguish two major methods of the colouring process - external or surface colouring of material and products, and internal or material colouring. The difference between these two methods can easily be shown by imaginary (or even real) cutting of the product. In the case of external colouring, the colour of the product is present only in its surface layer, in the case of material colouring, the colour is the same throughout its cross-section. The difference is also in how the colorant gets on the product or material. In material or internal colouring, the colours penetrate the product in the process of manufacturing, kneading the colorants into the material during the manufacturing process. In external colouring, the products are coloured after the manufacturing process, colouring only the product surface.

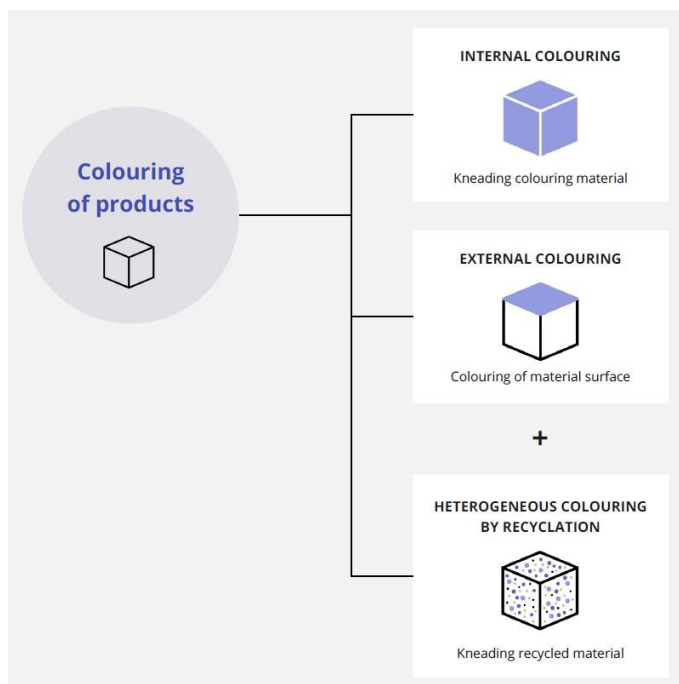


Figure 3: Colouring possibilities of products, including emerging method of colouring by recycling.
Author: Soňa Otiepková

With the current trend of recycling and creating new materials and products from waste materials, in addition to the above-mentioned methods of colouring products, another one appears, where the colour aesthetics of the final product is determined by the admixture of coloured pieces of waste materials. The resulting colour is not homogeneous and the outcoming

material or product can be called a composite. This method creates a new visual aesthetics, where the output colour of the product can be controlled only partially, by regulating the amount and colour of the admixed waste materials; the rest of the process is often left to a chance. As a result, each product is an original and they always slightly differ from each other.

The heterogeneous surface of the product, in which several colours and materials are mixed, is now becoming a hallmark of recycled products. These have increasing popularity among consumers who are starting to prefer them to conventional materials. [16]

CLASSIFICATION

In this research paper, we consider the approach of product and material designers and researchers to colour, in an ecological context, as a stand-alone design and material creation method. Within this main method, individual approaches can be classified into four basic principles (submethods), which the paper defines and describes. The main key and criterion to classification of these principles is, apart from the ecological aspect, the presence and importance of colour in the individual strategies combined with the nature and composition of the material to which this strategy is applied. Exemplary works of specific designers are given for each method for a better understanding of their essence.

Sustainable (progressive) colouring approach

The first method is the ecological colouring of materials and products, whereby the main role is played by the colouring process itself and the colour has an ecological basis. This means that designers and researchers use natural and ecological colours and dyes to colour individual materials and products. The emphasis in this approach is on experimenting with new colouring possibilities with as little negative impact on the environment as possible, or exploring original dyeing techniques that have a natural basis. In most cases, this approach counts with external colouring of products and materials.

One of the most innovative and progressive methods rising these days is bacterial colouring of textiles, which explores the potential of microbial pigments. One of the design researchers that devoted her work to exploring these possibilities is Ruth Lloyd, based in the United Kingdom. In her work, she *"has developed practice-based research focused on the creative potential of microbial pigments, investigating how these living colour systems present solutions and replacements to the global reliance on toxic petroleum-based colour and dye systems."* [17] Simply said, she is exploring the possibilities of dying natural textiles with the pigment produced by bacteria.

There is another design studio working with this technique, also based in the UK. The project is entitled Living Colour and draws attention to the importance of interdisciplinary collaboration, in this case a combination of design and science [18]. They managed to team up with global sports brand PUMA to create an experimental collection called *Design to Fade*, by which they

pointed out the possibilities of this technique in modern textile industry.



Figure 4: Samples of bacterial colouring of textile by Ruth Lloyd.
© Ruth Lloyd

Source: <https://2021.rca.ac.uk/students/ruth-lloyd>



Figure 5: Design to Fade collection in collaboration with Puma, where bacterial colouring was used.
© Ingo Foertsch

Source: <https://livingcolour.eu/design-to-fade/>

Another prospective colouring method, that has further potential in design and engineering, is the work of researchers from IST Austria and KAUST [19]. They have developed a new technique to create colour effects using a design tool and 3D printing. Their work goes beyond dyes and pigments as we know them. The researchers were able to recreate **structural colours**, known from nature, by 3D printed nanostructures: "In

contrast to pigment-based colours – where spectral components of incident light are absorbed by the pigment material – structural colorization arises from the interaction of light with micro- and nanostructures." [20] Structural colours are well-known from the nature – many natural organisms are given their colour from structural coloration. A good example of this kind of coloration is e. g. peacock feathers, "while the feathers appear to be brightly coloured (...), the feather itself is actually pigmented brown and it is the long hollows within the feather which reflect the bright colours." [21] In their work, the researchers combined computational design methods with additive manufacturing at the nanoscale to create such colour structure of surfaces. [20] This approach to coloration can be considered ecological from various points of view: "... structural colours enable more vivid colorizations (...), they do not fade over time and they do not need a wide range of potentially toxic pigments, because they can be fabricated out of a single inert substance." [20]

Lithuanian designer Agne Kucerenkaite revealed the value of industrial metal waste. In her project entitled *Ignorance is Bliss*, she explores how industrial metal waste can be turned into powdered dyes, which can be used to colour porcelain tableware and ceramic tiles. [22] She found the colour potential in the most unpromising of places – drinking water treatment sludge – and has been able to elevate a messy miscellany of minerals into high-value ceramics.



Figure 6: Ignorance is Bliss Porcelain Tableware coloured with metal waste from water sludge.
© Agne Kucerenkaite

Source: <https://www.agne-k.com/projects#/ignorance-is-bliss-porcelain-tableware/>

One more example of how innovative colouring technology can help to rediscover almost forgotten raw material: Karuun, a German company, managed to bring rattan that is considered sustainable material, back to the fore, by combining research and design. They discovered a simple but efficient way to colour this material by osmosis, with their self-built device that pumps colour into the pores of the material. The resulting material has not only promising properties, but also unique visual identity that the automotive industry is starting to notice. [23]



Figure 7: Samples of Karuun material – rattan coloured by osmosis,
© Karuun ®

Source: https://www.instagram.com/p/B-sAb_lqS_Z/?utm_source=ig_web_copy_link

Colouring of recycled materials

The second subgroup consists of the colour possibilities of recycled materials during their recycling process to form new products. In this subgroup, it is possible to observe two main approaches: 1. the recycled material needs to be fully recoloured in the process of forming new product; 2. there is no need to colour the recycled materials, because their original colours are incorporated and visible in the new product. Let us have a closer look at both of these approaches:

When recycling materials, there is a problem when mixing various coloured materials together – the outcome colour is brownish or greyish. Such colour might be unappealing and very hard to work with in further use. For now, there is no efficient system to colour-sort waste and recycling materials, so the recycled mixture needs to be coloured in order to put it back to the circular economy successfully. A very good example of how colour can help to make the recycled product more attractive is the project of French design students Hugo Maupetit and Vivian Fischer. They have developed a method for collecting discarded chewing gum and turning it into colourful, recycled plastic **skateboard wheels**. They coloured the recycled mixture of chewing gums with natural colours, so that the final product resembles its origin. [24]

Another approach when recycling materials is to use the original colour of the recycled materials and leave it visible in the new product. With this technique, the recycling material is not fully mixed together, but the coloured fragments of the material are of bigger size and the resulting colour is heterogeneous. This visual outcome can be considered an emerging trend in visual aesthetics of materials and products. As mentioned in the caption *Colouring of products*, this method does not fall into the

basic modes of colouring products (internal or external), so we can consider it to be a separate group. It is important to note that this method of recycling materials and products uses the long-lasting properties of mostly synthetic colours that outlasted the original products they were used for. They would not be able to decompose in the nature, so this attitude helps make the most of them.



Figure 8: Skateboard wheels from recycled chewing gums.
© Hugo Maupetit, Vivian Fischer

Source: <https://www.dezeen.com/2021/04/20/gum-skateboard-wheels-hugo-maupetit-vivian-fischer/>



Figure 9: Kave sneakers with rubber soles containing pieces of recycled worn out shoes.
© MgA. Eva Klabalová

Source: <https://www.kavefootwear.com>

More and more companies are incorporating this method of recycling into their portfolio. **Kave footwear** is a Czech footwear company, led by designer Eva Klabalová. The company designs ecological sneakers. In one of their lines, they incorporate coffee residues into the rubber sole of their sneakers, letting it be visible in the shoe soles. In other collection, they use worn shoes or residual pieces of rubber, which are mixed into each other in a special way. [25]

One of the most representative platforms that made the heterogeneous recycled surface popular in the world is **Precious Plastic**. Operating as an open-source platform whose technology can be used by anyone, they developed various machines to recycle plastics. Their philosophy is a combination of people, machines, platforms and knowledge to create an alternative global recycling system. [26] To create eye-catching and attractive products, they attempt to harness the colours of the waste materials they use and hand-sort them in order to control the output colour of the products.

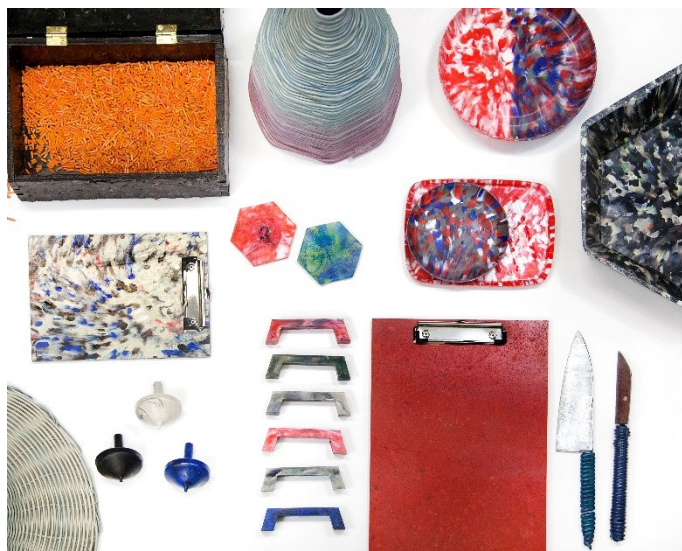


Figure 10: Samples of recycled plastic processed by various technologies.
© Precious Plastic Wien
Source: <https://preciousplastic.wien>

Colouring of bio-based materials

Another stand-alone subgroup of ecological approach to materials and products is bio-based materials and their colouring possibilities. The most popular bio-based materials are bioplastics. Several researches are underway in this field and there is interdisciplinary collaboration between designers and scientists. In this subgroup, the main goal is to expand the colour palette of bio-based materials, in a manner that their degradability or recycling possibilities are not reduced. In the material library called MaterialDistrict [27], we can see a cross section of the most progressive approach to creating new materials from natural resources. In this approach, it seems that materials themselves and their origin is in the spotlight, leaving colour in the background. But it is important to note that in the case of new bio-based materials, it is the colour that can become one of the deal-breakers that decides whether a given material will be successful in the current and future market and if it will be

able to replace oil-based materials. Besides, as the degradability is one of their main properties and features, the colorants used to dye these materials must have the same properties. In effect, along the development of new materials, parallel research must take place in the field of their colouring possibilities.

One of the companies that promptly reacted to growing demand for biodegradable colorants for bioplastics is a German company AF-colour. They developed and included in their portfolio colour masterbatches that are based on biodegradable carrier polymers. [28] Now their offer includes a broad colour range for colouring bioplastics, even though pigments used in these batches are not bio-based and further research regarding the degradability of used pigments needs to be done.

Finnish scientist Riikka Räisänen is working on a research directly dealing with the process of dyeing bio-based materials. Her research project BioColour: *"develops new methods for bio-based dye and pigment production and applications. Non-toxic and biodegradable colourants enable more sustainable solutions for textiles, coatings and packaging, which is a remarkable step towards bio and circular economy."* [29] In part of her research, she was able to successfully colour bioplastic material with bio-colorant called emodin [30]. In this project, they also aim *"to establish a biocolourant database. The database will contain information about supply chains of different biocolourants, but also their safety and quality (...). It will also enable large-scale utilisation of biocolourants in the future."* [29]



Figure 11: Samples of bioplastic Nuatan processed by various technologies.
© Crafting Plastics studio
Source: <https://www.craftingplastics.com>

For interesting colour samples of bioplastics processed by various technologies, we can have a look at the portfolio of a Slovak-based designer studio, Crafting Plastics. They are: *"... realizing dynamic research and innovation in materials and design (...) and explore new ways of developing products."* The

studio is also promoting interdisciplinary design focusing on circular design and the collaborative approach. [31]

Not only are bioplastics part of this subgroup, but there are many other bio-based materials using different natural resources to produce new materials that aim to provide sustainable alternative to traditional materials. Malai biomaterials is another studio of Slovak origin, currently based in India. They "*developed biocomposite material made from entirely organic and sustainable bacterial cellulose, grown on agricultural waste sourced from the coconut industry in Southern India.*" [32] Their material is available in a range of colours achieved through the use of natural dyes.



Figure 12: Colour possibilities of Malai biomaterial.
© Malai
Source: <https://malai.eco>

Reusing products through new colour solution of their coating

There is one more submethod of the ecological approach to the colour of products. This method could be characterized as a new colour solution for coatings and surface materials of products. Rather than recycling the entire product, its coating or surface material is replaced and the product reused. Although at first glance, it may seem that the colour is not present in this approach, or is present only marginally, the appropriate choice of colour of the new surface material or coating has the ability to restore the original product and bring it back into use. This also includes the design of new products in such a way that their worn-out surface material or coating does not degrade the entire product, but further use of the product is possible by simply replacing their surface layer with a new one. The replacement may take place not only in terms of wear and tear of the original surface, but also in terms of response to current and modern colour trends. The colour of the new coating material has the ability to make old-fashioned or outdated design more attractive by adapting it to new trends with a suitable combination of colours and patterns. This approach might be slightly less ecological than the other presented principles. But it may lead to a reduced consumption of materials and resources, especially for large products and furniture such as sofas or armchairs. A good example of an ecological approach

in replacing product coating is Ikea, with their design strategy. They offer various possibilities of re-coating their products.

CONCLUSIONS

The principles and approaches classified above have no fixed boundaries, they are not isolated. They influence or follow each other. Many designers are operating on their borders or in their intersections. This classification of the approach to colour in an ecological context has the main goal to enable us to talk about it more professionally and to attempt to define its importance and role in an individual approach. Based on research data, the following infographic aims to capture, where the colour enters the circular design process. The position on the circle is closely related with the colouring process of products and materials.

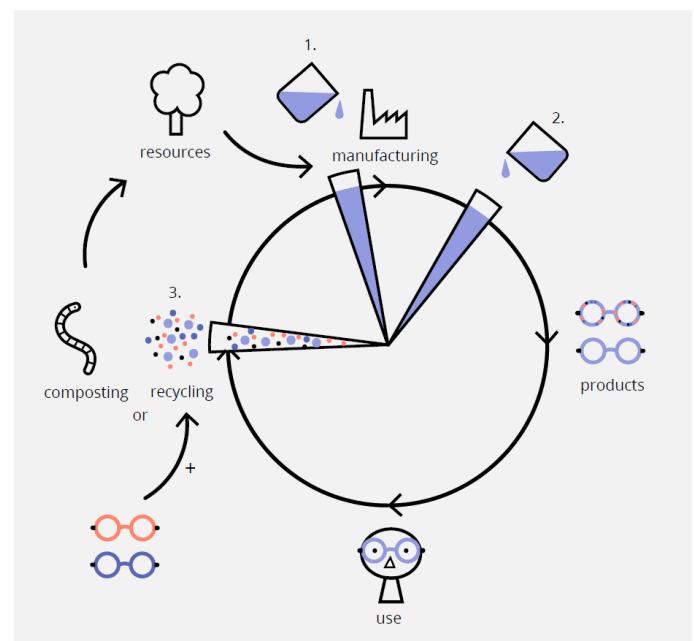


Figure 13: Points where the colour enters the circular design process.
Author: Soňa Otiěpková

The first point where colour can enter the process is manufacturing. In this phase, it is the internal or material colouring. The second point where colour can enter the process is post-manufacturing, before the product goes to market. At this point, it is external or surface colouring. The third point where colour can play a role in the circle is the recycling process. In the infographic shown above in this article, we used the term of heterogeneous colouring by recycling. At this point, the original colour of the product stays on the recycled pieces, to give colour and aesthetics to the new products.

It was not the intention of this article to draw a universal and definitive conclusion about this topic, because colour as such is one of the most relative notions. We know the perception of colour changes with concept, culture, light circumstances, time, etc. Also, it is impossible to create one unique concept or method of colour use in a circular design process. We need to start accepting more the relativity and instability of colour in order to use it more sustainably. It is important to capture and map different progressive approaches that use and highlight these properties of colour.

As implied by the research part of the article, colour is an integral part of the manufacturing process and we have to have it on mind to achieve real circularity. Further research of the individual parts mentioned in this article is needed, but on the examples of work of various designers, we could clearly see how colour can affect the process of changing human interaction with the environment and help close the circle.

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