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# Design Circular Colours: A cross-sectoral project for the systemic design of regional dyeing value chains

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# Design circular colours.

## *A cross-sectoral project for the systemic design of regional dyeing value chains.*

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Dyeing plants are an endemic resource that powered the European textile industry for centuries until the advent of synthetic pigments led to their complete abandonment. Today, interest in natural dyes is growing again, but the socio-technical complexity of modern supply chains requires more than technological updating. The problem must be framed through a systemic perspective that allows grasping the past and the present to foster a new, sustainable development of the sector. The ECOLOR project aims at investigating the development opportunities of natural dyeing value chains in the Piedmont Region (Italy), within a circular economy framework. Design acts as a process facilitator, mediating between different academic disciplines and multiple industrial and regional stakeholders to ensure a broad approach to the topic. The paper presents the methodology adopted, which combines the experimentation of industrial technologies with the exploration of socio-technical systems through specific systemic design tools, such as the Holistic Diagnosis, to define potential circular solutions. The study opens reflections on a multi-level approach to technology that does not neglect the socio-cultural dimension of local value chains. Moreover, it presents the potentials and limits of an interdisciplinary and cross-sectoral design process, laying the foundations for future implementation of local circular systems.

Keywords: socio-technical systems; sustainability transition; circular economy; dyeing plants; cross-sectoral collaboration

## Introduction

### The rise and fall of natural dyeing

Over five centuries, natural pigments have been central to the European textile industry, which has developed artisanal and, later, industrial knowledge and technology to extract colourings from local dyeing plants. In each country, textile districts have arisen and deeply influenced the social, urban, and even toponymy features of the cities involved. The import of better performing pigments from abroad soon changed the relationship between industrial production and local cultivation.

In the 20th century, the advent of synthetic dyes marked the end of dyeing crops, as they offered uniform hues at a much lower cost than natural pigments. Today, synthetic colours are still unrivalled, but in recent years, growing awareness of environmental sustainability has encouraged new programmes, supported by the European Union, to recover natural pigments. Indeed, natural substances' advantage is to reduce pathogenic and polluting effects and to offer vegetal by-products potentially recyclable in other supply chains.

However, optimising technological applications is not enough to give new impetus to natural dyes. We urgently need to reconsider the use, applications, know-how and social and industrial values of dyeing plants to foster a sustainability transition of the dyeing industry.

## From technical challenges to a systemic vision

The circular economy concept introduces an original approach to technology, as it comprises sustainable innovation within a broader economic model that is "restorative and regenerative by design and aims" (EMF, 2015, 2). Thus, it encourages production models that moves beyond mere process innovation. In this respect, a systems approach acknowledges the functioning of technology as a linkage between heterogeneous elements and embeds the technological dimension within a cluster of elements that fulfil societal functions: a socio-technical system (Geels, 2004; 2005). In the words of Hughes (1986), "disciplines, persons, and organizations in systems and networks take on one another's functions as if they are part of a seamless web." (p. 282).

In the 15th century as today, the interaction of heterogeneous professionals and organisations has generated different natural dyeing systems. However, today's scenario is undeniably more complex and poses important challenges from a social and technical point of view. Developing a circular dyeing chain requires technological experimentation to improve dye extraction and extend their application to new sectors (packaging, animal husbandry, nutraceuticals, among others). At the same time, technological solutions should be framed from a systems perspective (Farla et al., 2012), building a holistic vision of the socio-technical system in which actors and processes interact. Therefore, systemic design methods and tools can establish learning processes for understanding and developing circular systems (Pereno & Barbero, 2020), but also for co-designing new processes, services, systems and ways of living (Boehnert, 2018).

The ECOLOR project, funded by the EU ERDF programme 2014-2020, has this double aim. Firstly, to understand the past know-how and the state of the art of dyeing plants in the Piedmont Region (Italy) to define innovative industrial applications. Secondly, to design the value chain based on a systemic approach that fosters the development of a circular system, actively involving different disciplines and stakeholders.

The paper presents the methodology developed, the actors involved, and the expected results, proposing a reflection on the role of systemic design in developing socio-technical systems within a circular economy framework. The presented project (re)builds a decayed regional supply chain, and opens several possible pathways and reflections for practical implementation of systemic methods.

# Methodology

## Design as a facilitator of cross-disciplinary collaborations

Within the ECOLOR project, the design team acts as a facilitator at both process and creative input level, by coordinating different stakeholders in the design activities as well as in the broader system being affected by the project findings (Minder & Heidemann Lassen, 2018). The ability of "frame creation" (Dorst, 2015) is fundamental, as it allows systemic designers to go beyond technological borders to build a frame for analysing complex problems and defining innovative solutions within socio-technical systems. This ability allows designers to mediate between different disciplines, enhancing the co-creation of a project pathway aimed at valorising cultural and historical value chains, such as the dyeing plants one, from an innovative perspective.

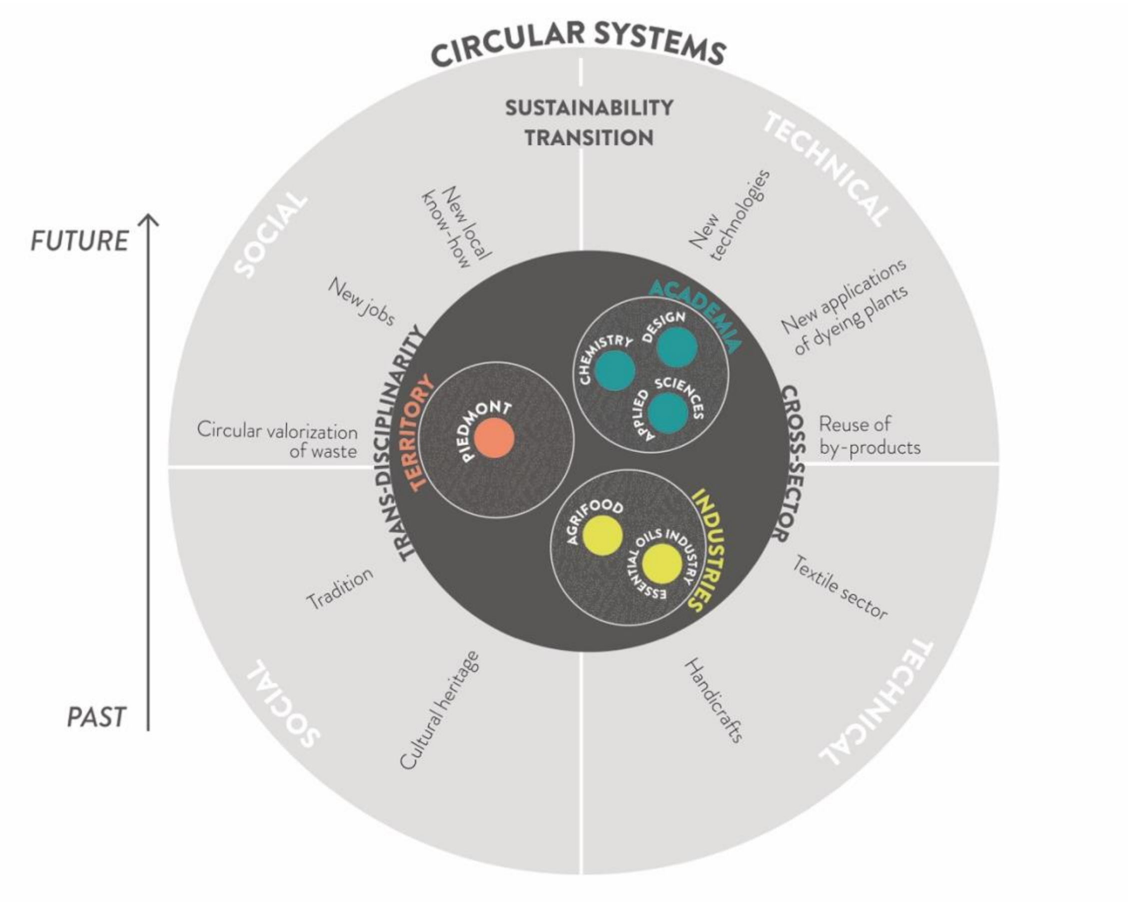


Figure 1. ECOLOR concept visualisation schema.

Figure 1 shows the research concept, which faces multiple tensions due to both the balance between different sectors and disciplines and the need to reconcile historical roots with a new social and technological context. Unlike other circular economy projects, we are not dealing here with a value chain undergoing transition but with a system that has died and must be brought back to life. This *'tabula rasa'* offers the possibility of making a major leap in the sustainable transition of dyeing industry, but at the same time the clash between different visions is delicate to manage. For some project partners, this is a matter of technological innovation, while it is crucial to work on the social impacts of the new model.

Indeed, the system must consider relations with the regional context, evaluating by-product valorisation solutions not only from a technical but also from a socio-environmental point of view: are new professions required? Is it possible to boost other local industries by promoting a sustainable transition? What impacts do the new crops have on local eco-systems?

This multiplicity of impacts necessarily requires close cooperation between different disciplines: Systemic Design and Applied Science and Technology from Politecnico di Torino, and Chemistry from the University of Turin. Two local SMEs are also involved: Agrindustria Tecco, which operates in the transformation of vegetal by-products into industrial value-added products, and Augusto Bellinvia, which deals with the extraction of flavourings and substances of natural origin. The cooperation with Proplast - Plastics Innovation Pole - underlines the strong relationship with the Region in which the project is located. Proplast is the co-manager of the regional innovation cluster on Green Chemistry and Advanced Materials. The cross-sectoral dynamics (European Commission, 2010) define a valid theoretical approach for the systemic exchange of competences between Academic Departments and Industrial partners involved, aimed at fostering a synergic work among all stakeholders.

## The methodological process

The operational steps of the research are structured in four main sections (Fig.2) that set out the timeframe of the work.

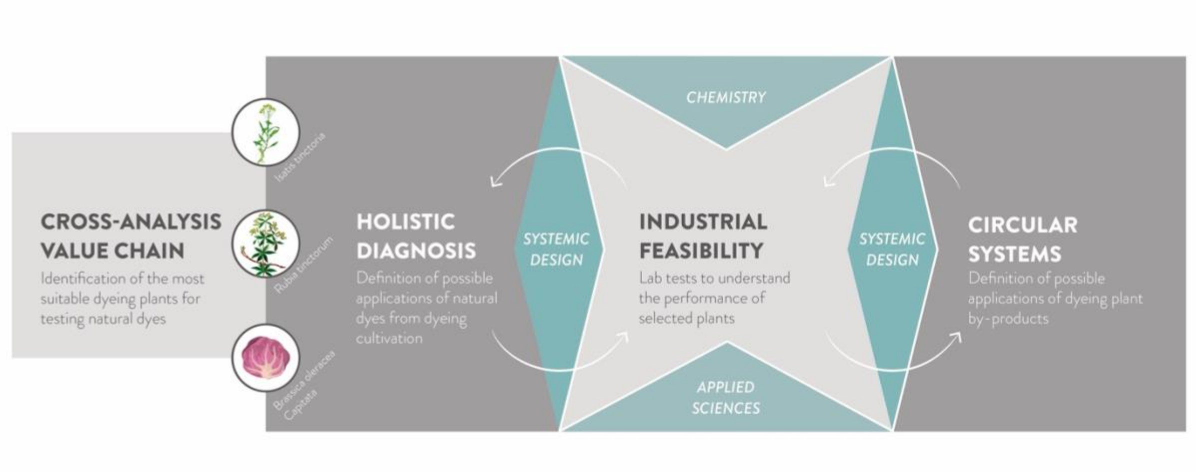


Figure 2. ECOLOR methodology steps schema.

**Cross-analysis of the value chain.** The first step provides the cross-analysis of local value chains, identifying which dyeing plants still exist and which ones can be re-introduced on the regional territory. This is a key step to understand the diffusion, the properties, the biological-morphological characteristics, but also the current uses and the critical points of use and management of the process by-products. This preliminary analysis led to the identification of three different types of crops from which to extract natural dyes. The *Isatis tinctoria*, which has strong historical and cultural roots in the Piedmont region, the *Rubia Tinctorum,* which has already been successfully tested, and the *Brassica oleracea Capitata* (red cabbage), which can be obtained from food waste and surpluses.

**Holistic Diagnosis.** Creating innovation, at any level and in any field, means first of all identifying and relating to a socio-cultural reference context, made up of people, stories, traditions and knowledge. To do so, after defining cross-analysis regarding the use of dyeing plants today, it is also crucial to prepare an analytical work step according to a holistic perspective (Battistoni, et al., 2019) of the territory, taking into consideration socio-cultural, environmental and economic aspects. The Holistic Diagnosis step helps at mapping the state of the art of the regional context, it takes advantage of different means of investigation, at different levels, from scientific data collection to semi-structured interviews, to provide an overview of the system's elements and their relations. All this information has to be visualised in an accessible way, capable of supporting data interpretation for a wide and inclusive variety of actors.

**Industrial Feasibility.** This first step focuses on the processing of dyeing products and the extraction of natural dyes. The industrial partners are in charge to identify the most suitable methods and parameters for grinding and drying the dyeing products; the Applied Technology team monitors the processes in real-time through spectroscopy tools. The second step concerns the testing of the dye extraction from vegetal substrates, assessing different extraction agents to optimise the process. Finally, the Chemistry team carries out the chemical characterisation of the colourants.

**Circular Systems definition.** In the final stage, the systemic design team carries out a detailed analysis of the dyeing by-products identified in the Holistic Diagnosis to define, with the support of chemists and engineers, the potentialities of different solutions. The aim is not just to assess the technological valorisation of by-products, but to systematise solutions to explore how they fit into the socio-technical system and can foster the development of cross-sectoral circular systems. The output of this process is a theoretical system in which heterogeneous professionals and organisations are interconnected, thanks to solutions that promote socio-economic models of circular economy, that is, restorative and regenerative models that enable the flow of material resources and know-how, based on an ongoing dialogue between stakeholders.

## Ongoing activities and expected results

The activities carried out in the ECOLOR project are aimed at defining the technical feasibility of new production processes for natural dyes and investigating the possibilities for the circular development of the value chain.

In this regard, the tangible example is highlighted concerning ongoing experiments on *Brassica Oleracea Capitata*. The aim of the experimentation is to address circular economy aspects from the raw material supply, intercepting surpluses, and production waste of this product for dyeing applications. This approach motivates the active involvement of different actors of the supply chain which sees the extension of the technical fields' application of the product.

Future projects will address the validation of dye processing and extraction technologies on a full industrial scale, as well as the organisational implementation of the circular model. The research is currently undergoing Holistic Diagnosis and, concurrently, the testing of pigment extraction from the three dyeing plants identified in the preliminary study.

Although still at an early stage, the research is expected to achieve short-, medium- and long-term results (see Table 1), bringing benefits to the three macro-areas identified in the concept phase: academia, industry, territory.

Table 1. Matrix of expected results in relation to timeframe and macro-areas involved.

| | ACADEMIA | INDUSTRY | TERRITORY |
|---|---|---|---|
| Short | Exploring co-design approaches between heterogeneous disciplines and organisations | Assessing the feasibility of new natural products and circular processes | Transdisciplinary and cross-sectoral collaboration between local stakeholders |
| Medium | Practical implementation of systemic design methods and tools in a circular value chain | Adopting a systemic approach to new circular business lines | Defining new systems for the valorisation of food waste and losses. |
| Long | Definition of cross-disciplinary methodologies for the sustainability transition of regional value constellations | Adopting a systemic approach to transitioning businesses towards a circular economy model | Giving new stimuli to an abandoned regional value chain and creating new job opportunities |

Each macro-area includes different academic, industrial and regional stakeholders (cf. Methodology), who have specific project goals and benefits, such as a new product or a pilot test. However, it is worth stressing how the transdisciplinary approach adopted and, in general, the pursuit of a systemic and circular model leads to a shared vision of the expected results. ECOLOR's experience already shows that a systemic perspective strongly influences the approach of the stakeholders involved. A technological pilot project on natural pigment extraction would have kept the focus on technological results. A circular design project, on the other hand, explores new technologies within the socio-technical system: in this perspective, the scope for experimentation is widened exponentially and a technological "failure" can be easily turned around for new cross-sectoral applications.

## Discussion and conclusions

The systemic approach at the heart of the study promotes research from a circular perspective, laying the foundations for the development of local and sustainable dyes in industry and considering the economic and environmental potential of the entire value chain. The industrial application sectors identified for further experimentation within new projects are food and cosmetic packaging, food industry, textiles and cosmetics. The risk of reducing research to technological achievements is high and would lead to little positive impact on the socio-environmental context. For this reason, the ECOLOR project aims to define all the possible impacts of circular solutions and the stakeholders that may be affected and involved.

The field of action expected is broad and increasingly interconnected, fostering continuous knowledge exchange through cross-sector academic and industrial partners. As a result, the complex issues need to be approached from multiple angles, regardless of "disciplinary boundaries" (Nicolescu, 2002, p.43). Hence, the next steps will allow the definition of an increasingly transdisciplinary research project, in which the inclusion of humanities could support the engagement of civil society. The designer's role is to mediate between technological innovation - necessary for industrial sustainable transition - and social and environmental impacts. These two aspects interpenetrate enhancing the definition of innovative processes capable of promoting cultural change.

The current research stage opens up the reflection on the challenges of co-design processes within trans-disciplinary and cross-sectoral teams, which are often affected by diverging objectives and technology-oriented approaches that overshadow systemic vision and medium- to long-term goals. This is further complicated when long-term projects are undertaken, as they should involve new professionals to respond to the needs in terms of sustainability of the industrial sector of natural dyes and their possible applicability.

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