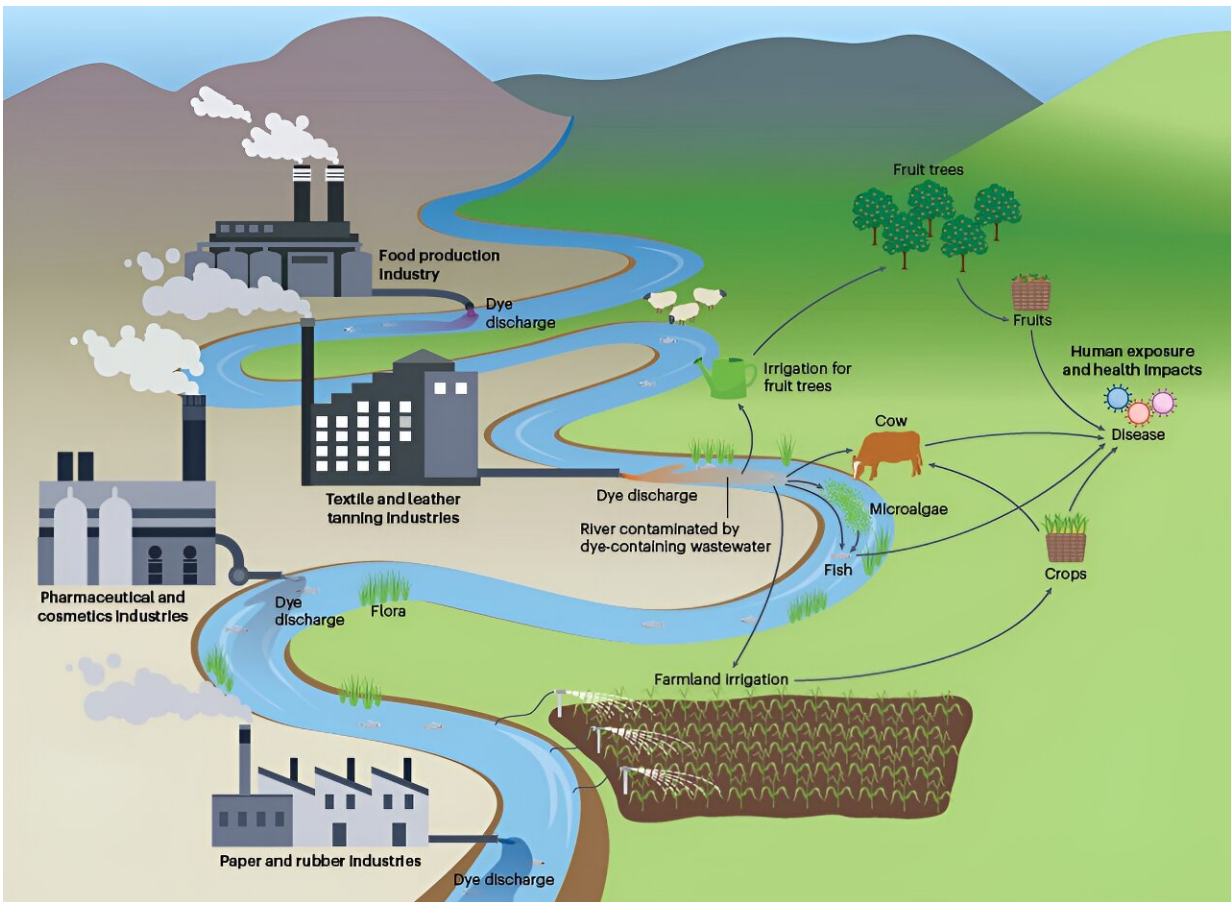


Do or dye: Synthetic colors in wastewater pose a threat to food chains worldwide

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Source of dye containing wastewater. Credit: University of Bath

Dyes widely used in the textile, food and pharmaceutical industries pose a pressing threat to plant, animal and human health, as well as natural

environments around the world, a new study has found.

Billions of tons of dye-containing [wastewater](#) enter [water systems](#) every year, and a group of researchers from the UK, China, Korea and Belgium say that new sustainable technologies including new membrane-based nano-scale filtration are needed to solve the issue, adding that legislation is needed to compel industrial producers to eliminate colorants before they reach public sewage systems or waterways.

Published today in *Nature Reviews Earth & Environment*, the study [Environmental impacts and remediation of dye-containing wastewater](#) was written by academics from the University of Bath, the Chinese Academy of Sciences, the Fujian Agriculture and Forestry University, the Korea Institute of Energy Technology (KENTECH), and KU Leuven, Belgium.

The research highlights that currently, up to 80% of dye-containing industrial wastewaters created in low- and middle-income countries are released untreated into waterways or used directly for irrigation. The authors say this poses a wide range of direct and indirect threats to human, animal and plant health.

Despite these severe threats to health and ecosystems, the authors underscored that there is inadequate infrastructure, investment and regulatory effort for making dye usage more sustainable, or for treatment of dye-containing wastewater.

Dr. Ming Xie, a lecturer in the Department of Chemical Engineering at the University of Bath (UK), believes that a multi-pronged approach is needed to combat the issue. He says, "Dyes create several problems when they reach water systems, from stopping light reaching the microorganisms that are the bedrock of our food chains, preventing their reproduction and growth, to more direct consequences like the [toxic](#)

[effects](#) on plants, soils, animals and humans."

"There are several potential ways to remove [dyes](#) from water including chemical, biological and membrane-based techniques, but different dyes required different approaches, and once they reach wastewater systems treatment processes can be highly energy intensive."

"A worldwide regulatory effort is needed to stop dyes reaching wastewater or other water systems such as irrigation. Given the complexity of treating dye-containing wastewater, one solution would be to shift from the concept of centralized or regional treatment methods, to decentralized and site-specific treatment at source, by compelling industries to remove dyes from the wastewater they create before it reaches public water systems."

Textile industry is biggest dye consumer

Mauveine, the first organic synthetic dye, was discovered in 1865, spurring the creation of the global dye industry. Since then, more than 10,000 different types of dyes have been synthesized, with annual global production today estimated at 1 million tons.

Dyes are used in the rubber, leather tanning, paper, food, pharmaceuticals and cosmetic industries, while the biggest user, the textile business, consumes 80% of produced synthetic dyes and generates about 70 billion tons of dye-containing wastewater annually.

China, India and Bangladesh combined discharge around 3.5 billion tons of textile wastewater each year. Water contamination is aggravated by synthetic dyes, which in light of water scarcity issues, makes dyes a fundamental environmental and sustainable development issue.

Untreated dyes cause coloration of water bodies, reducing the degree of

visible light that passes through the surface layer—hindering photosynthesis for [aquatic plants](#) and creating impacts along the food chain.

Microalgae, which form the foundation of the aquatic food chain, are most sensitive to photosynthesis reduction, suffering growth inhibition and cell deformation when exposed to a synthetic dye. This effect, and the knock-on suppressed transfer of energy and nutrients up the food chain, could lead to breakdown of entire aquatic ecosystems.

The effects have also been observed in fish. Dyes can deposit in fishes' gills, lateral lines or brains, leading to toxicological effects such as uncoordinated movement, respiratory distress, liver damage and kidney dysfunction. These effects not only reduce the nutritional value of the fish to predators, but also lower their reproductive rates. Toxic dyes can also bioaccumulate in the fishes' fatty tissue, presenting health risks to humans and animals throughout the [food chain](#).

Negative impacts of dyes are also found on land—where they disturb the balance of microbial communities in soil—and in humans. Exposure to dyes can trigger allergies, asthma and diseases including dermatitis and central nervous system disorders, as well as organ dysfunction and increased cancer risk.

No single treatment offers solution

The review explores the variety of remediation technologies for dye-containing wastewater, including chemical, biological, physical and emerging advanced membrane-based techniques. The authors found that no single technique presents a 'silver bullet' for removing dyes, while several promising methods are not yet technologically ready at scale.

In light of this, they suggest a collective effort, led by policymakers, to

increase the adoption of advanced remediation technologies and change textile processing methods to minimize the use of the most toxic dyes.

The authors also highlight a potential commercial impetus—the scope for industries to create new revenue streams from the processing, separation and reuse of wastewater materials.

Co-author Dr. Dong Han Seo, from the KENTECH Energy Materials and Devices/Environmental and Climate Technology Track, says, "Dye containing wastewater is one of the most challenging wastewater streams, which impacts lives and the environment in several countries."

"Our review provides the latest insight on how we can effectively manage the challenge from the perspective of circular economy, effectively recycling dyes from wastewaters using treatment strategies such as advanced membrane-based separation to recover both useful dyes as well as clean water."

Dr. Jiuyang Lin, from the Chinese Academy of Sciences, adds, "This review provides the examples on how we can reduce the dye footprints from production stages using new dyeing techniques. Guidance on effective solutions to dye containing wastewaters could be used to treat other challenging wastewater streams, safeguarding lives and the environment for future generations."

More information: Jiuyang Lin et al, Environmental impacts and remediation of dye-containing wastewater, *Nature Reviews Earth & Environment* (2023). [DOI: 10.1038/s43017-023-00489-8](https://doi.org/10.1038/s43017-023-00489-8)

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