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Chemical Dyes Used for Coloring Clothes and Their Impact on Human Beings

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Abstract:

Dyeing is the application of dyes or pigments on textile materials such as fibers, yarns, and fabrics with the goal of achieving color with desired color fastness. Dyeing is normally done in a special solution containing dyes and particular chemical material. Dye molecules are fixed to the fiber by absorption, diffusion, or bonding with temperature and time being key controlling factors. The bond between dye molecule and fiber may be strong or weak, depending on the dye used. Dyeing and printing are different applications; in printing, color is applied to a localized area with desired patterns. In dyeing, it is applied to the entire textile.

The primary source of dye, historically, has been nature, with the dyes being extracted from animals or plants. Since the mid-19th century, however, humans have produced artificial dyes to achieve a broader range of colors and to render the dyes more stable to washing and general use. Different classes of dyes are used for different types of fiber and at different stages of the textile production process, from loose fibers through yarn and cloth to complete garments.

Acrylic fibers are dyed with basic dyes, while nylon and protein fibers such as wool and silk are dyed with acid dyes, and polyester yarn is dyed with disperse dyes. Cotton is dyed with a range of dye types, including vat dyes, and modern synthetic reactive and direct dyes.

The textile industry is one of the important industries that generates a large amount of industrial effluents. Color is the main attraction of any fabric. Manufacture and use of synthetic dyes for fabric dyeing has therefore become a massive industry. Synthetic dyes have provided a wide range of colorfast, bright hues. However, their toxic nature has become a cause of grave concern to environmentalists. Use of synthetic dyes has an adverse effect on all forms of life. Presence of sulphur, naphthol, vat dyes, nitrates, acetic acid, soaps, enzymes chromium compounds, and heavy metals like copper, arsenic, lead, cadmium, mercury, nickel, and cobalt and certain auxiliary chemicals all collectively make the textile effluent highly toxic. These organic materials react with many disinfectants, especially chlorine, and form byproducts (DBPs) that are often carcinogenic and therefore undesirable. This effluent, if allowed to flow in the fields, clogs the pores of the soil resulting in loss of soil productivity.

Keywords: coloring, chemical, clothes, impact, dyes, human, beings, synthetic, carcinogenic, toxic, effluent.

Introduction

The textile dyeing industry has been in existence for over 4,000 years. Yet, textile dyes and their chemicals used in clothing manufacturing remain overlooked, as well as their negative impacts on people and the environment. [1,2]

Synthetic dyes not only harm your health but also destroy ecosystems and the planet. They produce toxic chemical waste that ends up in rivers and water sources and causes a lot of harm.

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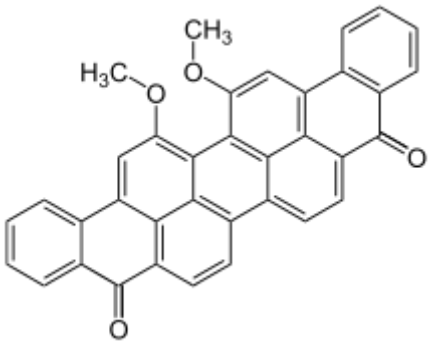
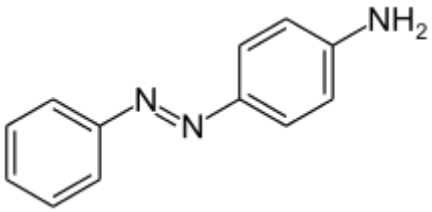


Chemical structure of Vat Green 1, a type of vat dye

Particularly in Asian countries like India, China, and Bangladesh, textile manufacturing factories produce and use dyes in harmful ways due to a severe lack of regulations.

Their protections for workers and the environment are weak. So fashion companies can produce their clothes, shoes, and accessories as cheaply as possible, disregarding environmental and health protection. Most dyes used for textile manufacturing, processing, washing, bleaching, dyeing, and garment finishing are toxic. Textile dyes often contain hazardous compounds that put the environment and your skin at risk.

Unfortunately, consumers have very low awareness of the impact of toxic dyes in the textile industry and their harmful effects on our health and environment.[3,4]



Aniline Yellow

Toxic chemicals in dyes and fabric treatments poison the air, drinking water, and soil used for agriculture. They are very damaging to ecosystems and human health.

The textile industry is responsible for discharging dyes along with a large number of industrial pollutants into the environment, which constitute 80% of the total emissions produced by this industry. Although dyes have been known to mankind since ancient times, it was not until the late nineteenth century that synthetic forms began to be manufactured, which are highly toxic and potentially carcinogenic.

Synthetic dyes used in textile and clothing manufacturing not only harm consumers but also farming communities and workers in garment-producing factories.[5,6]

These factories are often placed next to large waterways such as rivers or lakes because the production of textile dyes and their use in clothing manufacturing requires a lot of water.

The textile processing, dyeing, and treatment of clothes use tons of water and chemicals. And manufacturers discharge millions of gallons of chemically infected water into waterways every year.

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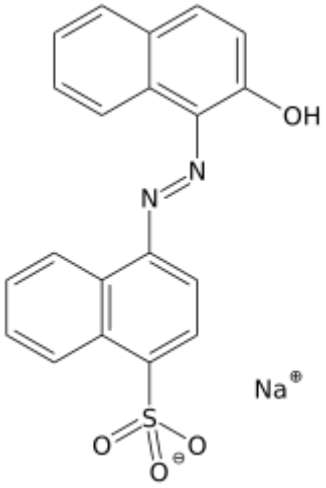
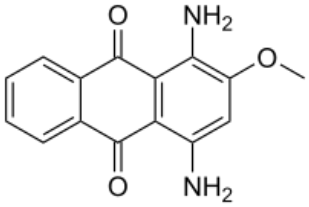


Acid red 88 is an acid dye used to produce red woolen yarns.

Apparel and textile products require 100 billion cubic meters of water annually for farming and manufacturing processes, as reported by the United Nations Economic Commission for Europe (UNECE). And a single fabric mill can use up to 200 tons of fresh water to dye one ton of fabric. Wastewater charged with harmful chemicals is often released untreated into nearby rivers, eventually spreading into the sea.

Polluted water is unsuitable for drinking and growing food. But the people and animals that live near the factories end up being sick from drinking the poisoned water or eating food grown from polluted soil. Toxic chemicals found in textile dyes include formaldehyde-based resins, ammonia, acetic acid, shrink-resist chemicals, optical whiteners, soda ash, caustic soda, and bleach.[7,8]

Nearly 800,000 tons of dyes are produced every year in the world, as reported by the National Institute of Oceanography and Fisheries. And it represents only a small part of the overall chemical industry.



Disperse Red 11

However, synthetic dyes are very valuable and used in numerous industries such as textile, paper printing, food, pharmaceutical, leather, and cosmetics. The largest consumer of these dyes is by far the textile industry.

More than 10,000 different dyes are used in textile manufacturing alone. Unfortunately, nearly 70% of them are azo dyes, which are complex in structure and synthetic in nature with carcinogenic evidence. The chemical classes of dyes frequently used on an industrial scale are azo, anthraquinone, indigoid, xanthene, arylmethane, and phthalocyanine derivatives. Still, the overwhelming majority of synthetic dyes in current use are azo derivatives.

They can be grouped in different classes: acid, basic, direct, disperse, metallic, mordant, pigment, reactive, solvent, sulfur, and vat dyes, which reflects their macroscopic behavior and also their prevailing functionalities.[9,10]

Reactive dyes are by far the most commonly used in textile manufacturing since they can be applied to both natural (cotton, linen, wool) and synthetic (polyester, nylon, acrylic) fibers. An estimated 280,000 tons of textile dyes are discharged in nearby industrial water globally every year, as reported by the University of Minho.

The large-scale production and extensive application of synthetic dyes cause considerable environmental pollution, making it a serious public concern.

Toxic textile dyes are one of the major causes of altering physical and chemical properties of soil, deteriorating water bodies, and causing harm to the flora and fauna in the environment.

Harmful dyes cause death to the soil microorganisms, which affect agricultural productivity. Azo dyes, in particular, are also highly poisonous to the ecosystem.

They are mutagens which means they have acute to chronic effects upon organisms, depending on the exposure time and azo dye concentration. Dyes are, in general, stable organic pollutants that persist in the environment and cause an increased biochemical oxygen demand. So they negatively affect living creatures in the long term in the discharged water.

Textile dyes are indeed created with a high fixation degree to fiber and fastness (i.e. high stability in light and washing) and are resistant to microbial attack.

So they are designed to resist very harsh conditions, making it extremely difficult to remove from textile wastewaters by the conventional wastewater treatments.[11,12]

The UNESCO reports that only 20% of globally produced wastewater receives proper treatment worldwide. It's time to prioritize water quality, reducing pollution, eliminating dumping, and minimizing release of hazardous chemicals and materials. Many dyes found in polluted wastewater have been linked to bladder cancer, splenic sarcomas, and hepatocarcinoma, producing nuclear anomalies in animals and chromosomal aberrations in mammalian cells.

Contaminated rivers become lifeless, all the fish are left to die and water turns to sludge. Polluted water, lack of algae, and chemical toxicity cause the death of aquatic life, ruins the soil and poison drinking water.

Some reactive dyes are recognised respiratory sensitisers. Breathing in respiratory sensitisers can cause occupational asthma and, once a person is sensitised, re-exposure to even very small amounts of the same dye may result in allergic symptoms such as a runny or stuffy nose, watery or prickly eyes, wheezing, chest tightness and breathlessness. Some dyes can cause allergic skin reactions. Certain reactive, vat and disperse dyes are recognised skin sensitisers.

A small number of dyes, based on the chemical benzidine, are thought to cause cancer – there are substitutes for these dyes in textile use.

Other dyes may also present hazards to health. It is essential to read the safety data sheet supplied with each hazardous product.[13,14]

Discussion

Long-term or accidental overexposure to toxic chemical dyes is also risky to human health. And the levels of exposure that workers generally face in the factories are unhealthy, to say the least.

Water pollution causes both environmental damage and diseases throughout local communities in developing countries. Many rivers are too polluted for any direct human contact.

Toxic chemicals in textile dyes cause most of the health problems related to dyeing and finishing processes. Synthetic reactive dyes are health hazards and cause respiratory issues due to the inhalation of dye particles.

They also affect the immune system and cause symptoms including itching, watery eyes, allergic reaction, sneezing, coughing, and wheezing, leading to illnesses such as asthma, dermatitis, and respiratory diseases.

Some trace metals found in dyes such as Cr, As, Cu and Zn cause several health problems, including hemorrhage, skin ulceration, nausea, and severe skin irritation. Synthetic dyes are non-biodegradable and carcinogenic and pose a major threat to health and the environment. People living near rivers turning into different colors have reported health problems due to polluted water and food grown in nearby fields. One of the better ways to make textile products without harming our environment is to use closed-loop manufacturing processes. They deploy closed water systems and recycle wastewater to protect the planet and save resources.[15,16]

Sustainable production facilities can almost fully recover and reuse water and chemicals with closed-loop processes. They are more environmentally responsible and promote high resource efficiency. A great way consumers can help and do their part to prevent the overutilization of dangerous chemicals in dyes is to look for certification standards like Bluesign or Oeko-Tex.

They guarantee sustainable production processes as well as high levels of safety both for human beings and the environment. Audits from third-party organizations confirm fibers' quality, safety, and eco-friendliness. Technology innovation allows more than 99 percent of the solvent to be recovered in a closed chemical loop and then fed back into the production process.

While harmful chemicals are still used in these manufacturing facilities, they aren't released into the environment and don't negatively impact ecosystems as much.

Some of the most environmentally friendly, socially conscious clothing items are Bluesign certified. Eco-conscious consumers looking for greener products of every kind can trust the Bluesign certification.

Bluesign is a sustainability standard that guarantees the highest level of security for consumers. It considers especially the chemical composition of textile products to ensure healthy and safe materials.

The Oeko-Tex certification is one of the world's best-known labels for textiles tested for harmful substances. It certifies high product safety and is widely used in the global apparel and footwear industry.[17,18]

The Oeko-Tex certification guarantees that products are harmless to the human environment. It takes into account many regulated and non-regulated substances, which may be harmful to human health. New clothes can be highly dangerous to your skin, especially when they receive chemical treatments to make them more colorful, flexible, soft, or water repellant.

Don't wear regular clothes without washing them. Thoroughly cleaning new fashion items you just bought helps remove a lot of toxic chemicals textile fibers have stored during production.

Pay particular attention to young children and baby clothing as they tend to have sensitive skin. Buying organic baby clothing is still one of the best things you can do as a parent.

The production of new clothes requires a lot of chemicals and raw materials, often made from non-renewable resources. The fashion industry causes tremendous amounts of air, land, and water pollution due to the overutilization of hazardous chemicals. 20% of industrial water pollution

globally is attributable to the dyeing and treatment of textiles, as reported by the Ellen MacArthur Foundation. Chemicals used in the production processes for fibers and textiles, such as dyes or finishing treatments, account for a significant amount of resource use, around 43 million tons in total.

Make sure to wash the clothes you buy before wearing them. Doing so will remove a lot of the harmful substances that stick to clothing during manufacturing.

Benzidine is a carcinogen that can affect the bladder. Dyes that are manufactured using benzidine as a parent compound contain very little benzidine in their finished form. However, it can be regenerated under certain conditions where chemical-reducing agents act on the dye. These conditions can occur during dyehouse processes such as dye stripping or following inhalation or ingestion. Some benzidine-based dyes may themselves be carcinogenic.

In practice, benzidine-based dyes should not be used but they are not specifically prohibited. Within textile finishing less hazardous substitutes have become readily available and there is no practical reason why they can't be used instead of benzidine-based dyes. In the unlikely event of being able to show sufficient justification for their continued use, you should take the following additional measures:

- Avoid dye-stripping, for instance by re-dyeing a darker shade
- Carry out any unavoidable dye-stripping in enclosed, ventilated vessels
- Prohibit the use of hand cleansers containing reducing agents such as sodium hydrosulphite

Benzidine congener dyes are based on substances chemically similar to benzidine, such as o-tolidine and o-dianisidine, both of which are also carcinogens. Find less hazardous substitutes for them, otherwise take these additional precautions with them.

Reactive dyes have a high degree of wet fastness because the reactive dye molecule fixes itself to natural materials such as cotton, silk, wool or leather by a strong chemical bond. If reactive dyes are inhaled or ingested they can react in the same way in the body. Sometimes this can affect the body's immune system. Changes to the immune system may mean the next time a person is exposed to the same reactive dye, their body reacts very dramatically, even if the amount of dye involved is very small. If this happens, the person is said to have become sensitised to that dye.

If the symptoms affect the lungs (often affecting the nose and eyes too) this is called respiratory sensitisation. If the symptoms affect the skin, this is called skin sensitisation. Reactive dyes may be respiratory and/or skin sensitisers, although skin sensitisation seems to be rare.

Evidence has shown that a number of reactive dyes have definitely caused respiratory sensitisation in the past. However, there is no validated test procedure for assessing the potential of any individual reactive dye to cause respiratory sensitisation. It is therefore prudent to handle all reactives as if they are respiratory sensitisers. This includes reactives used for dyeing wool.

The hazard to health from reactive dyes is only a concern before their application to the yarn or fabric. There is no known risk to anyone handling or wearing the dyed materials.[19,20]

Results

Natural, biodegradable dyes are the better alternatives for the environment and human health. They are non-toxic, low-allergenic, and free from any hidden nasties like lead, bleach, or nitrogen.

They are sourced from natural plant and biological materials for a muted, earthy-colored fabric, less vibrant and bright but more natural in appearance.

Each color dye is produced from a different plant. For example, red dyes can be made from beets or berries, black dyes from fruits of the *Terminalia cherbula* tree, and brown dyes from cutch wood, bark, or roots.

There are already many farmers and dye artists all over the world that make naturally dyed clothing. They promote transparency and human responsibility by working on family farms with localized manufacturing.

Non-toxic, natural, vegetable dyes are healthy and safe and focus on quality, not quantity. They promote ethical consumerism and care for the well-being of garment workers and the environment. The best clothing brands make organic essentials sustainably with non-toxic and natural dyes. They keep the people working in the supply chain and the products they sell safely.

One of the best ways to protect the environment and your skin is to buy and wear clothing made from non-toxic and natural dyes. Natural dyes made from plants, algae, fungi, or bacteria are eco-friendly bio-based alternatives.

Many ethical clothing brands create affordable and sustainable clothes in a fair and resource-efficient manner with non-toxic, natural dyes and organic materials. They avoid most chemicals used for textile manufacturing, washing, bleaching, and dyeing that are harmful to the environment, your skin, and the health of garment factory workers.

Check out our selection of the best organic fashion brands that make non-toxic clothing with natural, plant-based dyes.[18,19]

Here is what the experts have to say about the potential use of natural dyes in a new eco-friendly textile industry instead of harmful synthetics:

"Natural dyes are among the promising options for developing a greener textile dyeing process and such interest is reflected to the increased number of recent publications. Plant leaves are potential sources of natural dyes because of their easy availability and abundant nature."

- Mohammad Gias Uddin, Textile Engineer

"There has been a revival of interest in natural dyes in the global arena due to their non-polluting, non-carcinogenic and eco-friendly nature. [...] Natural dyes are biodegradable and do not cause any health hazards and hence they can be easily used without much environment concerns."

- Jyoti Arora, Prerna Agarwal, Gunjan Gupta, Research Engineer

"Nowadays natural dyes are one of the main areas of textile researches and important in terms of sustainable and ecological textiles, niche market and value-added unique textiles. [...] Especially wastes/by-products from food and beverage industries and agriculture are becoming increasingly popular as alternative and novel natural dye sources."

- Özlenen Erdem İşmal, Prof. Dr. PhD Textile Engineer

"For successful commercial use of natural dyes for any particular fibres, the appropriate and standardized techniques for dyeing for that particular fibre-natural dye system need to be adopted. Therefore to obtain newer shade with acceptable colour fastness behaviour and reproducible colour yield, appropriate scientific dyeing techniques/procedures are to be derived."

- Ashis Kumar Samanta, Prof. Department of Jute and Fibre Technology

"Textile industries are very useful for human being but these are destroying eco system because of generation of huge wastewater containing toxic substances. Prime reason of toxicity is use of synthetic dyes. To save our environment there is no alternative of natural dye."

- Arun Kanti Guha, Textile Engineer

"Many ancient cultures, such as ancient Peruvian cultures, used several types of natural organic dyes like indigo and carminic acid, to create highly complex ornamental patterns in their textiles, which reveals the knowledge of a wide range of skills to extract and to process natural dyes from plants and animals."

- Kramell, A.E., García-Altares, M., Pötsch, M. et al., Scientific Researcher

If toxic chemicals weren't enough already, dangerous heavy metals are also used in the dyeing processes. After being disposed of, these heavy metals enter our food chain through the irrigation of crops. For example, cadmium, lead and copper, which are found in dyes and pigments in clothing, accumulate in our bodies and can damage organs and our central nervous system.

Heavy metals can also increase the risk of various types of cancer, acute illnesses and skin problems. For example, chromium VI, mercury and cadmium can cause cancer. While the use of these heavy metals is strictly regulated in the EU, on a global scale, heavy metals in fashion are a real threat to human health.[17,18]

Symptoms of respiratory sensitisation

- Eyes: itching, watering eyes or swelling of the eyelids
- Nose: sneezing, itching, running nose or blocked airways
- Chest: symptoms of asthma, such as unusual breathlessness when running or playing sport; coughing, wheezing and chest.

Symptoms of skin sensitisation

- Redness or an irritating rash anywhere on the body, but commonly between the fingers or on the back of the hands and wrists

If someone exposed to reactive dyes displays one or more of these symptoms, you should investigate the possibility of sensitisation. Be aware, though, that the symptoms could be caused by, eg exposure to irritant substances commonly used in dyehouses.

The symptoms may happen immediately on exposure to the particular dye, in which case it will be relatively easy to identify the connection. However, a common pattern is that symptoms are delayed for several hours and are most severe in the evening or during the night. When symptoms are delayed, the affected person might not realise that the ill health is linked with their work - their first indication might come when they have a holiday away from the workplace and realise that the symptoms they have been suffering from have improved or even disappeared.

Five facts to remember about sensitisation

1. It is unpredictable. A number of colour-weighers may work with reactive dyes under exactly the same conditions. Some may become sensitised; others may suffer no adverse health effects at all
2. Most people who become sensitised to reactive dyes do so during the first two years of exposure but sometimes sensitisation happens years or even decades after starting to work with the dyes

3. It is all or nothing: you are either sensitised to a reactive dye or you are not
4. It is irreversible - you remain sensitised for life
5. People become sensitised to a particular substance and symptoms occur only in response to that substance - if there is no exposure then there will be no symptoms. However, a person who has become sensitised to one reactive dye may then be more likely to suffer adverse reactions to other dyes in the same chemical class.

If a person sensitised to a reactive dye continues to be exposed to it, their symptoms are likely to get worse. People who start off by reacting to the dye with a stuffy nose may go on to develop asthma. Asthma attacks are likely to become progressively more severe. Once asthma is established, an attack may be triggered by things other than the reactive dye, such as tobacco smoke or cold air. If this happens, the person may be left with occupational asthma for years after they stop working with the dye.[16,17]

Some people who develop occupational asthma become so disabled that they cannot work again - not only with dyestuffs but in any job. For some, a slow deterioration in their health caused by the occupational asthma means a shorter life expectancy. In extreme cases, a sudden, severe asthma attack could kill them.

So, it is very important that you take all practicable steps to reduce employees' exposure to reactive dyes, reducing the risk of anyone becoming sensitised. if someone does become sensitised, it should be recognised as quickly as possible so you can take steps to prevent their symptoms becoming worse.

Conclusions

To reduce the environmental impact of dyes in fashion, a more eco-friendly alternative is to dye clothes with bio-based dyes only. There are now a number of natural dyes based on plants, algae and even bacteria. Natural dyes may be less flashy, but they are far more respectful of the environment. Otherwise, dyes can also be obtained from by-products such as molasses. In any case, dyeing processes without chemicals, closed water systems and recycling of waste water are better alternatives for (slow) fashion brands to use

- Consider if there are less hazardous forms of the dyestuffs available. Choosing low-dusting dyes such as those in granular, dust-suppressed or liquid form can be a very important factor in reducing exposure. Remember that even liquid dyes can cause dust problems if spills are allowed to dry out
- Monitor batches of powdered dyestuffs closely and consider returning any unduly dusty product to the supplier
- Restrict access to the colour store to essential trained personnel. In some dyehouses, each dyer weighs their own dye and this tends to increase the chances of spillage and reduce the standards of housekeeping. It is better to have only one or two people do all the weighing, with proper training and precautions
- RPE should always be considered as a last resort:
- a number of factors can seriously affect its performance, so the protection afforded to the employee decreases dramatically, eg if a respirator is badly maintained, contaminated with dyestuff, not properly adjusted to the wearer or removed for even short periods while dust is airborne

- RPE does not protect against skin irritation
- wearing RPE all day may cause undue stress and discomfort to the wearer.

Individuals are in the best position to recognise any deterioration in their own health. However, unless they are informed and regularly reminded of the risks of sensitisation, they may not attach any significance to the early symptoms.[19]

Tell those who work with reactive dyes about:

- what sensitisation is and what can cause it
- what the early symptoms are
- the importance of reporting seemingly minor symptoms at an early stage
- who they should report symptoms to
- the risk of long-term breathing difficulties if exposure to a reactive dye continues after they are sensitised to it

Make sure that your training programme provides:

- guidance on how to handle dyes safely
- information on the arrangements for health surveillance and for reporting suspected symptoms
- the opportunity to ask questions
- opportunities for refresher training

Everyone who may be exposed to reactive dyes should be given training. Most obviously this will be the colour-weighers but it may include other dyehouse workers and laboratory and maintenance staff. Line managers and first aiders also need to understand the risks.

1) Reducing exposure

In general, you should handle reactive dyes in the same way as other dyestuffs – see (link to handling dyestuffs safely) above. Also consider the following:

Substitution

Where technical demands require the use of a reactive dye, choose the least hazardous form of the dyestuff available. The choice of low-dusting dyes such as those in granular, dust-suppressed or liquid form, can be a very important factor in reducing exposure. Remember, however, that dust will be released if liquid spills are allowed to dry or granules become ground down.

Dispensing

The whole process of dispensing powdered and granular forms of reactive dye, not just at the weighing stage, should be carried out under local exhaust ventilation (LEV). If the existing ventilation arrangements in your colour store will not accommodate dispensing dyes, you will need to provide a facility which does. In the interim, people working within the colour store should wear suitable respiratory protective equipment (RPE).

More information about LEV and RPE can be found at the following links:

- Respiratory protective equipment (RPE)
- Local exhaust ventilation (LEV) - workplace fume and dust extraction

2) Health surveillance

Health surveillance is appropriate for anyone at risk of being sensitised to reactive dyes. In practice, this means all colour-weighers and any maintenance staff involved in filter changing etc. However, there may be more workers at risk of sensitisation – this will depend on who dissolves the dye and how this is done.[20]

References

1. "Dyeing". The Free Dictionary By Farlex. Retrieved 2012-05-25.
2. "Dye". Merriam-Webster. Retrieved 2012-05-25.
3. Balter, M. (2009). "Clothes Make the (Hu) Man". Science. **325** (5946): 1329. doi:10.1126/science.325_1329a. PMID 19745126.
4. Kvavadze, E; Bar-Yosef, O; Belfer-Cohen, A; Boaretto, E; Jakeli, N; Matskevich, Z; Meshveliani, T (2009). "30,000-year-old wild flax fibers" (PDF). Science. **325** (5946): 1359. Bibcode:2009Sci...325.1359K. doi:10.1126/science.1175404. PMID 19745144. S2CID 206520793. Supporting Material
5. Barber (1991), pp. 223-225.[full citation needed]
6. Goodwin, Jill (1982). A Dyer's Manual. Pelham. ISBN 978-0-7207-1327-5.
7. Bhardwaj, H.C. & Jain, K.K., "Indian Dyes and Industry During 18th-19th Century", Indian Journal of History of Science **17** (11): 70-81, New Delhi: Indian National Science Academy.
8. Hans-Samuel Bien, Josef Stawitz, Klaus Wunderlich "Anthraquinone Dyes and Intermediates" in Ullmann's Encyclopedia of Industrial Chemistry, 2005, Weinheim: 2005. doi:10.1002/14356007.a02 355.
9. EPA Office of Compliance Sector Notebook Project: Profile of the textile industry. Office of Compliance, Office of Enforcement and Compliance Assurance, U.S. Environmental Protection Agency. 1997. p. 32. ISBN 978-0-16-049401-7.
10. Wingate, Isabel Barnum (1979). Fairchild's dictionary of textiles. Internet Archive. New York : Fairchild Publications. p. 571. ISBN 978-0-87005-198-2.
11. MATHEWS, KOLANJIKOMBIL (2017). Encyclopaedic Dictionary of Textile Terms: Four Volume Set. Woodhead Publishing India PVT. Limited. p. 464. ISBN 978-93-85059-66-7.
12. Mahapatra, N. N. (2019-01-31). Textile Dyeing. Woodhead Publishing India PVT. Limited. p. 159. ISBN 978-93-85059-91-9.
13. Weinhold, Virginia Beamer (1988). Interior Finish Materials for Health Care Facilities: A Reference Source for All Installations where Durable Surfaces are Needed. Thomas. p. 36. ISBN 978-0-398-05397-0.
14. Needles, Howard L. (1981). Handbook of Textile Fibers, Dyes, and Finishes. Garland STPM Press. ISBN 978-0-8240-7046-5.
15. Wingate, Isabel Barnum (1979). Fairchild's dictionary of textiles. Internet Archive. New York : Fairchild Publications. pp. 431, 432. ISBN 978-0-87005-198-2.
16. Clark, M. (2011-10-25). Handbook of Textile and Industrial Dyeing: Principles, Processes and Types of Dyes. Elsevier. pp. 8, 4. ISBN 978-0-85709-397-4.

17. The U.S. Textile and Apparel Industry: A Revolution in Progress : Special Report. Congress of the U.S., Office of Technology Assessment. 1987. p. 54.
18. Purushothama, B. (2019-01-31). Handbook of Value Addition Processes for Fabrics. Woodhead Publishing India PVT. Limited. pp. 83, 95. ISBN 978-93-85059-92-6.
19. Nayak, Rajkishore (October 2019). Sustainable Technologies for Fashion and Textiles. Elsevier. p. 243. ISBN 978-0-08-102867-4.
20. The Indian Textile Journal. Indian Textile Journal Limited. 2011. p. 37.