Journal of Geoscience and Environment Protection, 2022, 10, 87-99
https://www.scirp.org/journal/gep
ISSN Online: 2327-4344
ISSN Print: 2327-4336

The Impact of Face Mask Inks and Dyes on the Environment and Human Health

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How to cite this paper: Lakhouit, A., & Al-Rashed, W. S. (2022). The Impact of Face Mask Inks and Dyes on the Environment and Human Health. *Journal of Geoscience and Environment Protection, 10,* 87-99.
https://doi.org/10.4236/gep.2022.1012007

Received: November 3, 2022
Accepted: December 10, 2022
Published: December 13, 2022

Abstract

To reduce the impact of the novel SARS-CoV-2 virus, popularly known as the Coronavirus, many public health-related rules have been established around the world. Along with social distancing and lockdowns, most countries have mandatory wearing of face masks in public areas to limit the spread of the virus during the COVID-19 pandemic. However, because people are free to choose any method to make their masks, some are being fabricated from materials that can be toxic to the environment and human health. This paper discusses how inks and dyes used in face masks are causing major environmental degradation and health issues in industry workers and the general mask-wearing public. The goal fixed for the present study is to raise the alarm with authorities and decision-makers regarding the toxic nature of some colors (dyes and inks) and fabrics in the masks being worn every day.

Keywords

Face Masks, COVID-19, Coronavirus, Inks, Dyes

1. Introduction

In 2019, a new form of coronavirus (SARS-CoV-2) outbreak began in Wuhan, China, and the latter spread to the rest of the world. By March 2020, the World Health Organization (WHO) had named the illness "COVID-19" and declared it a pandemic. Measures and restrictions were introduced globally to halt the further spread of the virus, including lockdowns, social distancing, and public mandates. In particular, wearing masks and additional personal protective equipment (PPE) such as face shields and gloves became widespread in the public realm (Huang et al., 2020; Lakhouit, 2020). In many places, masks and face shields became mandatory by government order and had to be worn in public spaces such as schools, health care facilities, public transit, and shops. The masks were intended to protect the users and those around the wearer from disease transmission.

Face masks come in different shapes, sizes, materials, and quality. One thing they all have in common, however, is that they eventually end up as landfill waste. In most cases, there are no norms or standards regarding the kind of face mask that must be worn to comply with mandates, leaving the wearer free to choose the style of mask that appeals to them the most. The marketplace has responded by providing various types of masks, many adorned with slogans or other colorful designs. The application of color to mask material is made mainly for the purpose of aesthetics. However, many commercially produced dyes used for textiles are environmentally hazardous. Along with the toxic content of plastics, many textile dyes are likewise toxic and have long-term adverse environmental effects (Al Prol, 2019). Furthermore, many of the masks currently available on the market are constructed from plastic layers, which is detrimental to the environment and human health.

Despite the widespread use of masks due to mask mandates, very few people consider the potential health risks of wearing certain types of masks long-term, especially those produced with toxic dyes (Al Prol, 2019; Lellis et al., 2019). Commercial inks are made from chemical compounds, typically volatile organic compounds (VOCs). The negative impact of VOCs concerning human health is well-known and documented in the relevant literature (Lakhouit et al., 2016; Lakhouit et al., 2014). Furthermore, at room temperature, certain VOCs are highly transmissible as emissions, thus affecting not only the mask wearer but also those around the wearer. The current social and scientific interest stemming from heightened environmental awareness has given rise to several studies focusing on VOCs, including those on inks and dyes. BTEX (benzene toluene, ethylbenzene, and xylene) is a highly toxic chemical compound and VOC. Many researchers (Dai et al., 2017; Du et al., 2014; Kumar et al., 2018; Masih et al., 2017; Zhang et al., 2018) consider BTEX carcinogenic and extremely harmful to human health (Kumar et al., 2018; Masih et al., 2017). When not in compound form, benzene and ethylbenzene are still carcinogens that affect the nervous system, and toluene and xylene damage the reproductive and nervous systems. Beyond mask wearers, occupations in industries that produce or work with these toxic inks or dyes are at high risk for developing cancers and other chronic or fatal illnesses.

The adverse effects of masks on human health, especially the contained dyes in masks, are investigated during the present paper. The motivation of the present study is the lack of knowledge concerning masks and their constituents on human health and the environment. Masks contain dyes and different slogans sometimes. The impacts of these dyes are discussed in the present paper.

2. Materials and Methods

A careful risk-benefit analysis is becoming increasingly relevant for patients and their practitioners regarding the potential long-term effects of masks during the Covid pandemic. Hence, the main objective of the present paper is to investigate the adverse effect of masks on human health and the environment. In this optic, numerous scientific papers are collected and analyzed. The papers are chosen by using selected keywords as: 1) masks, 2) dyes, and 3) methods to eliminate dyes contained in masks in wastewater plants. During the present paper, face masks specifications are discussed in detail. The elimination engineering methods of dyes contained in masks are investigated. In the present only three methods of elimination of dyes are considered and these methods are: Physical, biological, and oxidation processes.

3. Results and Discussions

3.1. Face Masks Specifications

Masks are non-woven fabrics consisting of polypropylene, polycarbonate, polystyrene, polyethene, and polyester. Surgical masks usually consist of three layers (i.e., three-ply), with a polypropylene layer sandwiched between the non-woven fabric. Each layer has a different function (e.g., the melted brown inhibits microbial entry and acts as a microbial filter). This section usually helps to expand the mask, allowing the user to cover the nose to chin fully. Masks are mantled with head ties, ear loops, and elastic straps.

In general terms, masks are evaluated based on performance parameters, such as filtration, exposure, mask airflow resistance, etc. Filtration is crucial for microbial and aerosol filtration, including capturing aerosol exhalations. Mask performance is also appraised for its non-transference of aerosols from outside. Breathability or mask airflow resistance is also crucial and is based on pressure differences during breathing (Freeman et al., 2021; Kwong et al., 2021). Other performance parameters include liquid penetration resistance, water vapor and air permeability, water repellency (outer and inner surfaces) and fabric material (Li et al., 2006; Lee et al., 2020). In fact, mask dyes contain a number of organic solvents, such as toluene, ethyl acetate, isopropyl alcohol, etc., that cause direct and indirect health issues. Therefore, people wearing a mask on a daily basis are exposing their skin to chemical elements that have been known to cause skin rashes and other skin diseases. The skin's exposure to chemical dyes may even lead to cancer due to the carcinogenic nature of the dyes.

The impurity of chemical dyes is well recognized. Most of them have, for example, diluents, dispersing agents, and traces of unreacted dye intermediates. Furthermore, chemicals such as these can result in numerous health issues, such as chronic headaches, nausea, and skin rashes. They can also cause muscle and joint pain, fatigue, heart and lung problems, and even seizures. Children are particularly susceptible to chemical poisoning from dyes, because of their small size relative to adults. Signs of chemical poisoning in children typically include hyperactivity, behavioral and/or learning problems, and under-eye dark circles (Chavan, 2011).

Different dyes are available for different purposes. Mask requirements due to

COVID-19 preventative measures have led to a surge in several types of printed and semi-printed masks. Branding and fashion logos have become popular as well. However, no specific scientific studies exist that propose guidelines for the safe manufacturing of masks. With COVID-19 mask mandates as the "new normal," wearing unsafe masks could contribute to an additional health threat to the general population during the pandemic. The art of color application to enhance the appearance of fabric has been known to man since time immemorial. With increased industrialization over the past few decades due to globalization and increasing consumer demand, the textile industry is also rapidly expanding. In its pre-industrial phase, textile production relied mainly on eco-friendly natural dyes. However, because natural dyes generally gave only a limited and dull range of colors, synthetic dyes started to replace them. Today, with its wide range of fabrics, colors and shades, the textile industry is one of the most technologically complex industries. Large amounts of water are required in the textile industry for finishing and dyeing the product. Most commercially produced textiles use synthetic pigments and dyes. However, the finishing processes are relatively diverse concerning chromophore groups (e.g., anthraquinone groups, azo groups, indigoids, polymethines, xanthenes, phthalocyanines etc.) and application techniques. Nearly two-thirds of commercially produced dyes are derived from the azo group, which has strong chemical stability (Berradi et al., 2019). For example, there are water-soluble dyes (e.g., basic, acidic, reactive, direct, etc.) and water-insoluble dyes (e.g., sulfur dyes, vat dyes, etc.). In effluents from treated textiles, residual dye content creates both health and environmental issues, as the dyes can be toxic to flora and fauna. Even worse, because of the xenobiotic and high thermal/photostability nature of the dyes, they are mostly resisting biodegradation, which means they can stay embedded within an environment for a long period of time. Furthermore, when in sufficiently high concentrations, textile dyes that end up in water bodies prevent light from reaching the bottom of the water, negatively impacting the activity of the resident aquatic life, and hindering photosynthesis in aquatic plants (Liang et al., 2017). These changes in a water body can have major ecological consequences, including altering the very nature of the affected aquatic environments (Koupaie et al., 2012).

The dyes could impact the physical and chemical properties of the water body. This could include alterations to chemical oxygen demand (COD), high levels of biochemical oxygen demand (BOD), and detrimental changes in pH, suspended solids (TSS), and total organic carbon (TOC) (Croce et al., 2017). Also present in dyes are metals known as metalliferous pigments. Due to their extremely high toxicity, these pigments are known to lead to imbalances when present in biological treatment plants (Zaroual et al., 2006). Moreover, extended exposure to the pigments may result in health problems ranging from cancers (bladder, colon, colorectal, etc.) to reproductive and immune reproductive system problems (Jadhav & Srivastava, 2013).

As we can see from the above, extensive research has been conducted on the environmental hazards of effluents contaminated with residual dye content and color. However, very little research has yet been conducted on the risks to human health posed by dyestuffs used for textile dyeing and finishing. This is concerning, considering a large amount of textile dyeing currently occurring, particularly in developing nations. The following main factors may affect a dye's environmental concentration in the receiving water: 1) the dilution factor of the water; 2) the daily dye usage; 3) the degree of dye removal of the effluent treatment; and 4) the degree of dye fixation of the textile fabrics or fibers (Carmen & Daniela, 2012).

3.2. Textile Dyes Classification and Impact on Human Health

For many years, the textile production business has been rapidly developing, focusing on enhancing the fixation and optimization of the dye. This development adversely impacted the wastewater characteristics, the environment and human health (Khattab et al., 2020). Furthermore, some unfixed dyes (especially the darker ones) are washed into the environment during the dyeing process. When this occurs, regulatory bodies aim to get the textile producer to decrease the residual dye in the textile effluent (Hassaan & El Nemr, 2017). These effluents have dye chemicals and trace metals (e.g., Cu, As, Cr, Zn), many of which are non-biodegradable and potentially carcinogenic.

Furthermore, because of their aromatic structure and synthetic nature, the effluents can cause significant health problems, ranging from skin irritation to ulceration to hemorrhage. In addition, textile effluents may contain microbial and organic impurities beyond those mentioned above. The dye 1,4-diamino benzene, classified as an aromatic amine, has parent azo dyes that cause a wide range of health issues on skin contact, including contact dermatitis, chronic lacrimation, permanent blindness, vomiting, acute tubular necrosis supervenes, and vertigo. Aromatic amines are mobilized via fluids such as water and sweat, enabling their ready absorption through exposed skin, including the mouth. If the dye is ingested, it can cause edema of the tongue, neck, pharynx and larynx, and acute respiratory distress. Dyes ingested are potentially more dangerous, considering that a larger amount of dye may be absorbed in a shorter time (Puvaneswari et al., 2006).

Azo dyes classified as aromatic compounds can result in acute and chronic toxicity due to their adsorption and breakdown products (i.e., toxic amines). **Table 1** demonstrates several groups of common textile dyes. The toxicity impacts the skin, lungs and gastrointestinal tract, disrupts blood formation, and forms hemoglobin adducts. Some processes used to treat the effluents include trickling filters, flocculation, and electrodialysis, but unfortunately, these treatments are generally ineffective for dye removal.

3.3. Elimination of Dyes Contained in Masks

3.3.1. Physical Method

Although flocculation-based physical methods and coagulation have been proven

Table 1. Classification of different groups of textile dyes.

S. No	Dye	Types	Dyed fiber	References
1	**Acid Dye (anionic)**	1) Azo 2) Anthraquinone, and 3) Triarylmethane.	wool, nylon, nylon/cotton blends, acrylics, and silk	(Suresh, 2014)
2	**Basic dye (cationic)**	1) Crystal violet, 2) Safranin, 3) Basic fuchsin 4) methylene blue.	wool, silk, cotton, and modified acrylic fibers	(Suresh, 2014)
3	**Direct dyes**	1) Phthalocyanine, 2) Stilbene or 3) Oxazine	cotton, other cellulosic fibers, paper, leather, wool, silk and nylon.	(Suresh, 2014)
4	**Reactive dye**	1) Vinyl sulphone (e.g., c.i. reactive black 5) 2) Chloro/fluoro triazine (c.i. reactive red 3) 3) Chloro/fluoro pyrimidine	Cellulosics, silk, nylon and wool.	(Suresh, 2014)
5	**Disperse dye**		cellulose acetate, polyester, nylon, triacetate, and acrylics	(Burkinshaw, 1995)
6	**Mordant dye**	1) Hematein (natural black 1) 2) Eriochrome cyanine r (mordant blue 3) 3) And celestine blue b (mordant blue 14).		(Suresh, 2014)
7	**Vat dye**	1) Quinonic, 2) Anthraquinones 3) And indigoid dyes.	Cotton, wool and other fibers.	(Sala & Gutiérrez-Bouzán, 2012)

to be effective ways to decolorize dispersed dyes in wastewater, such approaches are much less efficient when applied to vat or reactive dyes. These techniques produce a large quantity of sludge, limiting their use (Liang et al., 2014). Adsorption, whose primary influencing parameters include particle size, pH, temperature, contact time, adsorbent surface area, and interaction of the dye and adsorbent, is one of the most successful and tested treatments with potential uses in textile wastewater treatment. Amino nitrogen-containing adsorbents generally have a large adsorption capacity when interacting with acid-based dyes. Activated carbon is currently the most-used adsorbent for textile wastewater. However, other low-cost options are derived from agricultural or industrial wastes, such as coal ashes and fuel, bentonite and modified bentonite, rice husk and hulls, wood chips and sawdust, ground sunflower seed shells, and tree bark. These can be used to remove dye successfully and other colored matter from effluents. The recorded removal rates for textile effluents are 40% for direct dyes and 40% - 90% for basic dyes, while adsorption rates for basic dyes have been recorded at a maximum of 338 mg/g (Anjaneyulu et al., 2005). Over the years, various adsorption techniques have been widely used, largely due to their efficiency in decolorizing dye-containing wastewater (Jadhav & Srivastava, 2013). Activated carbon has also been demonstrated to be an efficient adsorbent that is useful in removing most dyes; however, it is also costly and has difficulties in regeneration, making it a less popular choice for decolorization (Galán et al., 2013).

3.3.2. Oxidation Process

Oxidation comprises the most-used method of degrading dyes by chemical means due to its ease of application and high efficacy (Javaid & Qazi, 2019). However, the reaction parameters such as pH, temperature and concentrations should be optimized to enhance the dye removal performance. The oxidation technology can be classified as either advanced oxidation processes (AOP) or chemical oxidation. AOP is a process in which hydroxyl radicals (•OH); are powerful oxidizing agents that are the most powerful oxidizing agent after fluorine (Nidheesh et al., 2018). Chemical oxidation methods use oxidizing agents like ozone (O_3) and hydrogen peroxide (H_2O_2). Note that Ozone and H_2O_2 form strong non-selective hydroxyl radicals at high pH values.

AOP also includes dye removal methods such as electrochemical oxidation, photolysis and sonolysis (Crini, 2006). **Table 2** shows different methods used to reduce the impact of dyes on our environment and human health.

3.3.3. Biological Process

Although biological approaches for textile dye removal are favorable for their environmentally friendly methods, biological processes in textile effluents can remove only dissolved substances, with removal efficiency heavily dependent on the organic load/dye to microorganism load ratio. Moreover, the biodegradation capacity is influenced by the dye's chemical properties (i.e., pH, salinity) (Bhatia et al., 2017; Hadibarata et al., 2013). The efficiency is also affected by the system's oxygen concentration and temperature. Biological methods are based on oxygen requirements and are categorized as anaerobic, aerobic, facultative, anoxic, or a combination of these features (Jadhav & Srivastava, 2013). Nevertheless, these approaches are not only environmentally friendly but also cost-effective

Table 2. Oxidation methods for degradation of dyes.

S. No	Type of oxidation process	Treated dye	Result	Ref
1	UV/H_2O_2	Azo dye Reactive Green 19 (RG19)	Complete decolorization within 20 min. Around 63% of Total organic carbon (TOC) was eliminated in 90 min.	(Zuorro & Lavecchia, 2014)
2	Combinations of TiO_2/UV/H_2O_2	Azo dye Amaranth (AM)	The decolorization efficacies were 17%, 26%, 38% and 64% for UV, UV þ H_2O_2, and UV þ TiO_2.	(Gupta et al., 2012)
3	Hydrogen peroxide in subcritical water	Reactive Red 120	The experimental temperature is linked to the rate of H_2O_2 change to hydroxyl radical radicals (0.5% w/v). Hydrogen peroxide was ideal for degrading RR120 at all dyes concentrations and temperatures.	(Daskalaki et al., 2011)
4	Hydrodynamic cavitation with the existence of (H_2O_2, CCl_4) and Fenton's reagent.	Rhodamine B	Decolorization of Rhodamine was at 99.9%, utilizing a combination of cavitation and H_2O_2 and a combination of cavitation with Fenton chemistry.	(Mishra & Gogate, 2010)

Table 3. Microorganisms' cultures used in the degradation of different dyes.

S. No.	Microorganisms	Dye type	Results	Ref.
1	White rot fungus *Pleurotus eryngii* F032	Naphthalene	1,4-Naphthaquinone, benzoic acid and catechol are metabolites resulting from naphthalene biodegradation. The optimal decolorization was attained at pH 3 and 40˚C.	(Hadibarata et al., 2013)
2	White rot fungus *Coriolopsis sp.* (1c3)	Triphenylmethane dyes (TPM)	94%, 97% and 91% decolorization was observed for Crystal Violet (CV; 100 mg/l), Methyl Violet (MV; 100 mg/l) and Cotton Blue (CB; 50 mg/L), within 7, 7 and 1 day(s) respectively.	(Chen & Ting, 2015)
3	*Aspergillus niger*	Remazol Brilliant Blue R (RBBR) and Acid Red 299 (NY1)	Recombinant and native laccases showed similar decolorization (40% - 60%) for Remazol Brilliant Blue R within 200 min.	(Benghazi et al., 2014)
4	*Pseudomonas sp.*	Reactive Blue 13	83% decolorization at HRT of 70 h.	(Lin et al., 2010)
5	*Aeromonas jandaei* SCS5	Methyl red (MR)	Complete decolorization of MR at 100 mg/L and HRT of 6 h.	(Sharma et al., 2016)
6	Bacterial mixed cultures SB4	Remozol Orange	Decolorized 0.2 μg/L of RV5 in ~18 h.	(Jain et al., 2012)

and produce less sludge than conventional methods (Hayat et al., 2015). Membrane bioreactors are among the most common methods for bioremediation of impurities in the environment, including textile dyes (Spagni et al., 2012; Prabha et al., 2017; Al-Rashed & Lakhouit, 2022). Moreover, the literature has shown numerous studies that have proven the efficient use of individual and microbial consortiums with dye concentrations of up to 1000 mg/L (Kurade et al., 2017; Lade et al., 2015; Rajendran et al., 2015). **Table 3** presents more details on biological treatment methods.

4. Recommendations & Conclusion

In most countries, the general population has been mandated to wear face masks during the COVID-19 pandemic as a measure intended to decrease the impact of respiratory infectious viruses on human health. According to scientific investigations, face masks can substantially negatively impact human health and the environment, depending on the materials used to fabricate them. For commercial purposes, many masks with different colors and slogans have been sold, with synthetic dyes and inks used to write these slogans. The effects of dyes and inks on human health are well-documented in scientific literature. Therefore, the face mask industry should be strictly controlled and regulated, as should the materials used to manufacture the masks. Eliminating or mitigating the adverse impact of dyeing masks could be accomplished through various approaches. It has been established that the unintended negative impacts of mask usage, not only on the users but also on the workers in the masks industry and the environment affected by the textile effluents, are extremely serious. Masks should be free of slogans or other dye-produced decorations on their surface. At the same time, dyes need to be selected and applied in accordance with internationally accepted industry standards to protect human health and the environment. Furthermore, international consensus needs to be reached regarding face mask dyes and inks, as particular dyes are toxic (e.g., Azo dyes) and can have significant negative human health impacts and negative impacts on the ecosystem.

The waste masks should be collected and disposed of as medical waste. The public need to be educated and encouraged to wear their masks for the proper usage period before replacing them or properly sanitizing them; this will directly impact reducing the volume of wasted masks. Potential research should focus on eco-friendly treatment methods, such as advanced oxidation processes coupled with biological degradation, employing large-scale experiments with feed from textile production wastewater plants. One of the disadvantages of some novel treatment methods (e.g., membrane bioreactor) is the lack of economic study; thus, future researchers should consider this aspect to prove the approach's feasibility.

Acknowledgements

The authors of this paper thank the (Deanship of scientific research at the University of Tabuk).

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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