APPLICATIONS OF HIGH-VISIBILITY GARMENTS - A REVIEW

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Abstract

High-visibility clothing is designed to enhance the visibility of individuals, thereby reducing the risk of accidents in various settings. These garments typically utilize fluorescent materials for daytime visibility and retro reflective elements for low-light conditions. They are commonly worn by workers in environments with moving vehicles or machinery, such as construction sites, roadways, and railways, as well as by cyclists and motorcyclists to increase their conspicuity on the road. Standards like ANSI/ISEA 107 in the United States and ISO 20471 internationally categorize these garments based on the level of visibility required for specific job functions. However, recent studies have raised concerns that certain high-visibility clothing may interfere with modern vehicle detection systems, potentially reducing their effectiveness in ensuring pedestrian safety. Ongoing research and development are focused on integrating smart textiles and sustainable materials to enhance the functionality, comfort, and environmental impact of high-visibility apparel.

Keywords: *High-visibility clothing, Retroreflective elements, ANSI/ISEA 107 standard ISO 20471 standard*

1. INTRODUCTION

High visibility (hi-vis) garments are specialized clothing designed to enhance the wearer's visibility, especially in low-light or hazardous environments. These garments are typically made using fluorescent colors like neon yellow, orange, or green, combined with reflective strips that enhance visibility under artificial light or headlights. Hi-vis clothing is essential for ensuring worker safety in industries such as construction, roadwork, mining, and manufacturing, where employees are exposed to moving vehicles, heavy machinery, or poor lighting conditions. By improving visibility, these garments help reduce the risk of accidents and ensure compliance with safety regulations set by occupational health authorities. (Fekety, D.K., 2015).

2. OBJECTIVES OF REVIEW

This paper aims to assess the effectiveness of fluorescent colour in enhancing worker visibility. It reviews the evaluation of reflective materials employed for nighttime visibility. an analysis of design, comfort and a review of existing safety standards is included

DEFINITION OF PURPOSE

High-visibility clothing, often abbreviated as hi-vis, refers to garments made from materials that are highly luminescent or easily distinguishable from any background. These garments are typically fluorescent in colors like yellow or orange and may include retroreflective strips to enhance visibility in various lighting conditions. The primary purpose of high-visibility clothing is to enhance the wearer's visibility, thereby reducing the risk of accidents, especially in environments where there are moving vehicles or machinery. This is crucial for occupations such as railway and road workers, airport personnel, emergency responders, cyclists, and hunters, where being easily seen can prevent accidents and save lives. By wearing high-visibility garments, individuals ensure they are easily noticeable, which is a critical factor in preventing accidents and enhancing overall safety in various occupational and recreational settings.(Chanani, S., 2022)

KEY VISIBILTY FACTORS

Fluorescent Background Material:
Color Selection: Utilizing bright, fluorescent colors such as neon yellow, orange, or green enhances visibility during daylight hours. These colors are chosen for their ability to stand out against most backgrounds.
Retroreflective Material: Reflective Strips: Incorporating retroreflective strips into the garment ensures that light is directed back toward its source, significantly improving visibility in low-light or nighttime conditions

Standards and Regulation:

ANSI/ISEA 107: In the United States, this standard specifies the design and performance requirements for high-visibility safety apparel, ensuring garments provide adequate visibility.
ISO 20471: This international standard outlines the requirements for high-visibility clothing, including test methods and performance criteria, to ensure consistent quality and effectiveness (Oliveira, J 2021).

PRINCIPLE OF HIGH VISIBILITY GARMENT

Fluorescence for Daylight Visibility: Fluorescent materials in colors like neon yellow, orange, or green absorb ultraviolet (UV) light and re-emit it at longer wavelengths within the visible spectrum. This process, known as fluorescence, makes the fabric appear exceptionally bright, enhancing visibility during daylight hours (Lilienthal, A.J., 2014)
Retroreflection for Low-Light Conditions: Retroreflective materials are engineered to reflect light back toward its source, ensuring that wearers are visible in low-light or nighttime environments. This property is crucial for scenarios where artificial lighting, such as vehicle headlights, is present (Arditi, D, M. and Lee, D.E., 2003)

MATERIALS AND TECHNOLOGIES USED

Fluorescent Materials
Fluorescent materials are engineered to enhance visibility during daylight hours and in conditions with ample ultraviolet (UV) light. They contain special pigments that absorb invisible UV light and re-emit it as visible light, resulting in a brighter and more vivid appearance than standard colors. This property makes them particularly effective during dawn, dusk, or overcast days when natural light is limited. Common fluorescent colors used in high-visibility clothing include yellow, orange-red, and red.

Retroreflective Materials

Retroreflective materials are designed to reflect light back toward its source, making them highly effective for nighttime visibility or in low-light conditions. They achieve this through microscopic glass beads or prismatic elements embedded within the material, which redirect incoming light directly back to its origin. This characteristic ensures that, when illuminated by a light source such as vehicle headlights, the material appears exceptionally bright to the observer.(Cabral, I.2024).

ADVANCES IN SMART AND ADAPTATIVE VISIBILITY FABRIC

Adaptive Thermal-Moisture Management:
Innovations in smart textiles include fabrics that respond to temperature and moisture changes, maintaining wearer comfort without the need for external heating or cooling. These textiles utilize responsive materials and structures to dynamically regulate thermal and moisture levels (Cunha, J., 2024)
E-Textiles with Integrated Electronics:
The incorporation of electronic components, such as sensors and LEDs, into fabrics has enabled functionalities like real-time monitoring and adaptive responses. These e-textiles can enhance safety by providing additional visibility features and health monitoring capabilities

DURABILITY AND PERFORMANCE CONSIDERATIONS

Material Quality:
High-quality retroreflective materials may have higher costs due to advanced technologies used in their production, but they offer enhanced durability and performance.
Standards Compliance:
Adherence to standards, such as ISO 20471, ensures that high-visibility fabrics meet specific performance criteria, including luminosity and colorfastness, which are essential for maintaining visibility over time**. (**Blackburn, R. and Joslin, R., 2021**)**

APPLICATIONS IN VARIOUS INDUSTRIES

Construction and Roadwork: Workers in construction zones, especially those near roadways, are at heightened risk due to moving vehicles and heavy machinery. High-visibility clothing ensures they remain conspicuous to drivers and equipment operators, thereby mitigating potential hazards**.**

Transportation and Warehousing: Personnel involved in loading and unloading goods, as well as those operating within warehouses with vehicular traffic, benefit from high-visibility apparel. Such clothing enhances their visibility, reducing the likelihood of accidents in bustling environments.

Emergency Services: First responders, including police officers, firefighters, and paramedics, often operate in high-risk scenarios, such as roadside emergencies or disaster sites. High-visibility garments ensure they are easily identifiable, facilitating swift assistance and coordination.

Railway and Airport Operations: Employees working on railways and airports are frequently in proximity to moving vehicles and equipment. High-visibility clothing is crucial in these settings to prevent accidents and ensure smooth operations.

Cycling and Motorcycling: Cyclists and motorcyclists are vulnerable road users. Wearing high-visibility clothing enhances their presence on the road, making them more noticeable to other motorists and thereby reducing the risk of collisions.(Chowdhury, N. and Ma, P., 2022).

Hunting: Hunters often wear high-visibility clothing, such as blaze orange vests, to prevent accidental shootings by making themselves easily distinguishable from game animals and other hunters. (Chowdhury, N,2022).

Table 1 lists global standards of high visibilty garments

TABLE 1 International standards for high visibility clothing

STANDARD	REGION	DESCRIPTION
ANSI/ISEA 107	USA	Established by the American National Standards Institute, this standard defines three classes of high-visibility garments based on the level of risk and required visibility. Class 1 offers the least visibility, while Class 3 provides the highest. The standard also specifies design requirements, including the amount of fluorescent and retroreflective material.
ISO 20471	INTERNATIONAL	Published by the International. Organization Standardization, this standard specifies requirements for high-visibility clothing capable of visually signaling the user's presence. It includes criteria for color and retroreflection, as well as minimum areas and placement of materials.
ENISO 20471	EUROPE	This European standard specifies requirements for high-visibility clothing capable of signaling the user's presence visually, intended to provide conspicuity of the wearer in hazardous situations under any light conditions by day and under illumination by vehicle headlights in the dark.

PERFORMANCE AND EVALUATION TESTING

Color Performance Testing

Hi-vis garments use fluorescent materials to enhance daytime visibility. Testing involves measuring chromaticity coordinates and luminance to ensure colors meet specified thresholds, maintaining high contrast against various backgrounds.

Retroreflective Performance Testing

Retroreflective materials are crucial for nighttime visibility. The coefficient of retroreflection measures how well these materials reflect light back to its source. Testing involves using devices like retro reflectometers or gonio-photometers to quantify this property, ensuring materials meet required standards.

DURABILITY AND ASSESMENT

Abrasion Resistance: Determines how materials withstand wear from friction.
Weathering Tests: Expose materials to UV light, moisture, and temperature variations to assess colorfastness and material integrity over time.
Laundering Tests: Evaluate the impact of repeated washing on the garment's visibility features, ensuring they remain effective throughout the product's lifespan. Wear and Environmental Impact on Performance
Impact of Wear and Tear Regular use subjects hi-vis clothing to wear and tear, which can compromise its visibility features:
Physical Damage: Holes, rips, and abrasions can reduce the garment's surface area, diminishing its visibility. Such damage necessitates immediate replacement to ensure safety.
Reflective Material Degradation: Over time, reflective strips may peel, crack, or fade, especially if not properly maintained. This degradation impairs nighttime visibility, increasing the risk of accidents. (. Tang, S. and Stylios, G.K., 2006)

Environmental Factors

Ultraviolet (UV) Exposure: Prolonged exposure to sunlight can cause fluorescent colors to fade, reducing daytime visibility.
Chemical Exposure: Contact with oils, solvents, or other industrial chemicals can degrade both fluorescent and reflective materials, compromising the garment's effectiveness.
Weather Conditions: Adverse weather, such as rain, snow, or fog, can obscure visibility.

MAINTENANCE AND REPLACEMENT

Regular Inspections: Routine checks for signs of wear, fading, or damage is essential. Garments exhibiting significant deterioration should be promptly replaced. Following manufacturer guidelines for laundering and storage helps preserve the garment's visibility features. (Gambatese, J.,2020) The disposal of hi-vis garments has ecological implications. A significant portion of used hi-vis clothing ends up in landfills, contributing to environmental pollution. Choosing eco-friendly hi-vis apparel made from recycled materials can mitigate environmental impact while maintaining safety standards. By acknowledging the effects of wear and environmental factors, and implementing proper maintenance practices, the performance and longevity of hi-vis garments can be optimized, ensuring continued safety for workers.

COMPARATIVE ANALYSIS OF GARMENT DESIGNS

1. **Classification of Hi-Vis Garments**

The American National Standards Institute (ANSI) and the International Safety Equipment Association (ISEA) categorize hi-vis garments into three classes based on the level of visibility they provide:
Class 1: Designed for workers in environments with minimal traffic moving at low speeds. These garments offer the least amount of fluorescent and reflective material.
Class 2: Suitable for workers in areas with higher traffic speeds and complex backgrounds. These garments provide more visibility than Class 1, making them ideal for roadway construction sites and emergency response scenes.
Class 3: Offers the highest level of visibility, intended for workers in high-risk environments with high-speed traffic and limited sight distances. These garments include additional reflective material on the arms and legs to ensure 360-degree visibility. Each class is designed to address specific work conditions, ensuring that workers have appropriate visibility based on their environment. (Joslin, R., 2021)

2. **Color Choices**

Hi-vis garments primarily come in two fluorescent colors: orange and yellow/lime. The choice between these colors depends on the work environment:
Hi-Vis Orange: Stands out against natural backgrounds like greenery, making it suitable for outdoor environments such as forestry or construction sites surrounded by vegetation.
Hi-Vis Yellow/Lime: Highly visible in both daylight and low-light conditions, making it effective in urban settings or areas with artificial lighting. The human eye detects yellow hues more readily, enhancing visibility.
Selecting the appropriate color enhances worker visibility and safety in specific environments. (. Kim, M. and Song, C.S., 2021)

3. **Material Composition**

The materials used in hi-vis garments significantly impact their effectiveness:

Fluorescent Materials: Enhance visibility during daylight hours by absorbing and re-emitting light, making the garment appear brighter. (Sayer, J.R. and Mefford, M.L., 2004)
Retroreflective Materials: Reflect light back to its source, crucial for nighttime visibility. The arrangement and quality of these materials affect the garment's overall performance. Innovations in material technology have led to the development of garments with improved durability and visibility, ensuring long-term safety for worker.

4. **Design and Conspicuity**
The design of hi-vis garments, including the placement of reflective strips and the complexity of the background, plays a vital role in their effectiveness:
Reflective Strip Placement: Strategically placing reflective materials on the torso, arms, and legs ensures visibility from all angles. (Christie, R.M., 2011)
Background Complexity: In environments with complex backgrounds, garments with more extensive reflective coverage are necessary to distinguish workers from their surroundings.

CHALLENGES AND LIMITATIONS

High-visibility clothing can sometimes be uncomfortable, especially in hot or humid conditions, leading to reduced compliance among workers. Ensuring that these garments are ergonomically designed to allow ease of movement and are made from breathable materials is crucial to promote consistent use.Uncomfortable or poorly designed high-visibility garments may result in workers not wearing them correctly or at all, thereby compromising safety. The reflective properties of high-visibility garments can degrade over time due to exposure to sunlight, washing, and general wear and tear. Regular inspection and timely replacement are necessary to maintain their effectiveness. Proper care is essential to preserve the functionality of high-visibility features. Failure to follow recommended washing and storage guidelines can lead to premature deterioration, reducing the garment's lifespan.

Textile Waste: The production and disposal of high-visibility clothing contribute to environmental pollution and increased textile waste. The fashion industry, including high-visibility apparel, significantly impacts the environment through resource consumption and waste generation.Some high visibility garments are treated with chemicals to enhance their reflective properties, which can be harmful to the environment. For instance, France has implemented a ban on 'forever chemicals' (PFAS), harmful substances used in numerous consumer products, including textiles and clothing, to make them waterproof or stainproof. The fashion industry is increasingly recognizing the need for sustainable practices. Initiatives aimed at reducing the environmental footprint of textile production and promoting the recycling of materials are being implemented to address these concerns. (Pereira, C. 2014)

FUTURE TRENDS AND INNOVATION

Developments in e-textiles enable garments to monitor environmental conditions, such as temperature and humidity, providing real-time data to both the wearer and external systems, thereby improving safety and comfort. Some high-visibility garments now feature embedded LED lights powered by flexible batteries, enhancing visibility in low-light conditions beyond traditional reflective materials. The use of organic fibers, recycled polyester, and biodegradable materials is on the rise, aiming to reduce the environmental impact of high-visibility clothing production. Companies are developing fully recyclable high-visibility workwear, allowing garments to be reprocessed at the end of their lifecycle, thereby minimizing waste. (Islam, S.,2016) Balancing durability with recyclability presents challenges, as materials designed for longevity may be harder to recycle. Ongoing research aims to develop textiles that are both durable and recyclable. Modern high-visibility garments are being designed to offer additional functionalities, such as weather resistance and integrated communication tools, catering to the diverse needs of various industries.

CONCLUSION

High-visibility garments are essential in enhancing worker safety by increasing visibility, thereby reducing the risk of accidents. The global market for these garments is projected to grow significantly, from US$16.9 billion in 2023 to US$30.5 billion by 2034, driven by stringent workplace safety regulations and heightened awareness. However, challenges persist, including the potential for high-visibility clothing to interfere with modern vehicle detection systems, potentially diminishing their effectiveness in certain conditions. To address these issues, future research should focus on developing materials compatible with both human vision and advanced vehicle sensors, enhancing the durability and comfort of eco-friendly fabrics, and integrating smart technologies to adapt to varying environmental conditions. These efforts aim to ensure that high-visibility garments continue to provide optimal safety across diverse scenarios.

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