

## **FROM HAZARD TO HOPE: EMPOWERING SANITATION HEROES WITH WEARABLE INNOVATION**

### **AUTHORS**

Dr. Kundlata Mishra

Associate Professor, Fashion Design Department, National Institute of Fashion Technology, Mumbai

Ms. Shweta Rangnekar

Assistant Professor, Fashion Design Department, National Institute of Fashion Technology, Mumbai

Corresponding Author: kundlata.mishra@nift.ac.in

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### **ABSTRACT**

In India, manual scavengers, often from the low socio-economic group, endure hazardous conditions as unsung heroes of sanitation, providing a crucial service to society. As India achieves technological milestones, there is a growing imperative for local designers to contribute to a society focused on collective progress. This research explores the design of smart wearables capable of detecting harmful gas levels in sewers, addressing a critical need. Sewage cleaners, predominantly from marginalized communities, face daily challenges, including exposure to toxic gases like hydrogen sulfide, methane, and carbon monoxide. Alarming statistics, such as the estimate of 5 million sanitation workers in India (Dalberg Associates, 2018) and the distressing fact that one worker dies every five days due to gas exposure (Source: National Commission for Safai Karamcharis, 2019), emphasize the urgency of the study. Aligned with the vision of Prime Minister Shri Narendra Modi's Swachh Bharat Abhiyan, a nationwide campaign for a cleaner India, this research aspires to set new standards by proposing performance clothing designs integrating compact and efficient electrochemical sensors. These sensors aim to provide better living and working conditions for sanitation workers from disadvantaged backgrounds, offering timely alerts to workers and supervisors, averting accidents and saving lives.

The comprehensive study involved analyzing existing research, patents, and design concepts related to protective clothing and wearable technology in hazardous environments. An interview schedule was developed, and field surveys and interviews (n=30) were conducted with sewage workers, supervisors, and stakeholders to understand specific challenges and gather feedback on potential designs. The collected data was evaluated to determine the proposed design's effectiveness on worker safety, comfort, and overall well-being. Based on feedback and analysis, the authors developed design solutions prioritizing comfort, mobility, and durability while acknowledging the physiological requirements of sewage cleaning professionals.

In the words of Mahatma Gandhi, "The best way to find yourself is to lose yourself in the service of others." This research strives to honor the service of sewage cleaners by offering them a lifeline through innovative, life-saving technology, ultimately aiming to uplift a marginalized community, creating a positive future society through the integration of wearable technology in the performance clothing segment.

## 1. INTRODUCTION

### 1.1 SANITATION WORKERS AND THEIR PLIGHT

Sanitation workers, integral to the sanitation chain, play a pivotal role in ensuring our separation from human waste, a vital societal function often overlooked. However, these unsung heroes, primarily from the stigmatized caste of 'Dalits' in India, face hazardous, stigmatizing, and underpaid conditions. The caste system confines them to these roles, perpetuating the burden of inheritance, stigma, and exploitation. A 2018 study by Dalberg Associates identified 5 million sanitation workers across various urban locations in India, encompassing different roles along the sanitation value chain. From cleaning sewers to domestic work, these workers, lacking protection, face direct exposure to human waste, resulting in health hazards (Berg, 2021). Tragically, an estimated three sanitation workers succumb every five days in India, with countless others enduring infections and injuries, impacting their families (Nair, 2018). While in past only the government departments employed sanitation workers, newer opportunities in present times, such as employment in shopping malls, have emerged. However, the individuals involved and their backgrounds largely remain the same. Manual scavenging, a particularly challenging form of sanitation work, involves direct contact with human faeces without support systems or protective gear, predominantly affecting women.

Despite historical reforms and legislative efforts, including the ban on manual scavenging in 1993, followed by the Prohibition of Employment as Manual Scavengers and their Rehabilitation Act in 2013, the exploitation persists. Media attention often focuses on fatalities during sewer or septic tank cleaning, but the extensive vulnerabilities of sanitation workers and



Figure 1: Manual scavengers cleaning the drain

their communities during their daily lives remain unseen. Concerns are growing, especially with the large-scale construction of toilets under the Swachh Bharat Mission. The use of technologies requiring periodic emptying and off-site treatment of fecal matter raises apprehensions among organizations advocating for sanitation workers' welfare. Without proper sanitation systems and mechanized cleaning, there is a risk of exacerbating the undignified practice of manual scavenging, particularly in rural areas, further compromising the vulnerability of sanitation workers.

### 1.2 PRESENT DAY PERSONAL PROTECTIVE EQUIPMENT

In India, the Occupational Safety, Health, and Working Conditions Code, 2020, is a comprehensive legislation that

covers occupational safety and health standards for various sectors, including sanitation work. The mandatory Personal Protective Equipment (PPE) for sanitation workers include durable and protective clothing to shield workers from direct contact with waste, harmful chemicals, and other hazardous materials. Heavy-duty gloves to prevent hand contact with waste and protect against cuts, abrasions, and exposure to chemicals. Sturdy and chemical-resistant boots to protect the feet from injuries and contact with hazardous substances. Safety goggles or face shields to shield the eyes from debris, chemicals, or any other potential hazards. Depending on the nature of the work, masks or respirators may be required to protect workers from inhaling harmful gases, dust, or particulate matter. Helmets or hard hats to protect against head injuries, especially in environments where there is a risk of falling objects. However the reality and the implementation of these laws is far from ideal in the country (Bhatt, 2022). Existing protective solutions for sewage cleaners are rudimentary, comprising basic masks and gloves. These offer limited defense against the lethal gases present in sewage systems. The absence of real-time monitoring exacerbates the vulnerability of these workers, as evident in alarming statistics, including the estimate of 5 million sanitation workers in India (Dalberg Associates, 2018) and the distressing fact that one worker dies every five days due to gas exposure (Source: National Commission for Safai Karamcharis, 2019). This underscores the critical need for innovative and technologically advanced protective gear. In the year 2021, the government of India launched Safai Mitra programme and invited uniforms for the septic tank cleaners. Figure 2 showcases the protective clothing designs sanctioned.

### 1.3 INTEGRATION OF WEARABLE TECHNOLOGY



Figure 2: Safai Mitra Uniforms for sewer/ septic tank entry

The ongoing technological advancements are driving a comprehensive transformation across global industries. Concurrently, industrial control and safety systems are progressing from isolated standalone setups to interconnected systems that seamlessly communicate and exchange vast amounts of data. The Internet of Things (IoT) is playing a pivotal role in exponentially influencing the entire business landscape (Dude, 2015). It achieves this by interconnecting all objects and devices integral to specific activities or businesses. IoT represents a collective assembly of entities, encompassing anyone, anything, anytime, anyplace, any service, and any network capable of interacting with one another. This interconnectedness signifies a paradigm shift in the way industries operate, fostering a more dynamic and integrated approach to business processes (Tang, 2010).

## **2. OBJECTIVE OF THE STUDY:**

The paper aims to provide dignified design solutions to the sanitation heroes. The objectives of the study are as follows:

- To analyse and review the existing personal protective equipments available for the sanitation workers for need identification
- To develop a comprehensive design framework for smart wearable protective gear tailored to the unique challenges faced by sewage cleaners
- To explore integration of advanced technologies for real time monitoring with protective clothing that prioritise safety and comfort while acknowledging their physiological requirements.

## **3. RESEARCH METHODOLOGY:**

A qualitative research was conducted through developing an interview schedule for the sanitation workers, and through observation study and field surveys for need assessment. The ethics committee approval was sought to conduct the interview schedule and the respondents' privacy was maintained. The responses from a total of 30 respondents were analysed. The selection of the respondents was done through convenient sampling method. Through observation study to study the physiological requirements to perform the job work and perspectives of participants in their natural setting and their reaction to the proposed uniform designs. The authors also connected with the researchers from CIRCOT, Mumbai (Central Institute for Research on Cotton Technology) for understanding the research and development being carried out for developing smart wearables at the research institute as well.

## **4. RESULTS AND DISCUSSION:**

### **4.1 DEVELOPMENT OF A COMPREHENSIVE FRAMEWORK**

Designing uniforms for sewage cleaners requires careful consideration of practicality, safety, comfort, and ease of maintenance. By bringing in a conceptual design thinking process it lays a strong foundation in designing and developing the protective clothing and integration of wearable technology. The final product needs to meet the functional, safety, comfort and aesthetic needs of the wearer. The authors for the same propose a comprehensive conceptual framework (figure 3) to design the protective clothing.

### **4.2 NEED ASSESSMENT SURVEY**

Through convenient sampling method, 30 sewage cleaners, supervisors and stakeholders were selected for an interview schedule. The needs of the workers were analysed to understand the preferences of materials, colors, trends, garment details and designs that support the functionality and yet provide safety to the wearer in a dignified manner. One

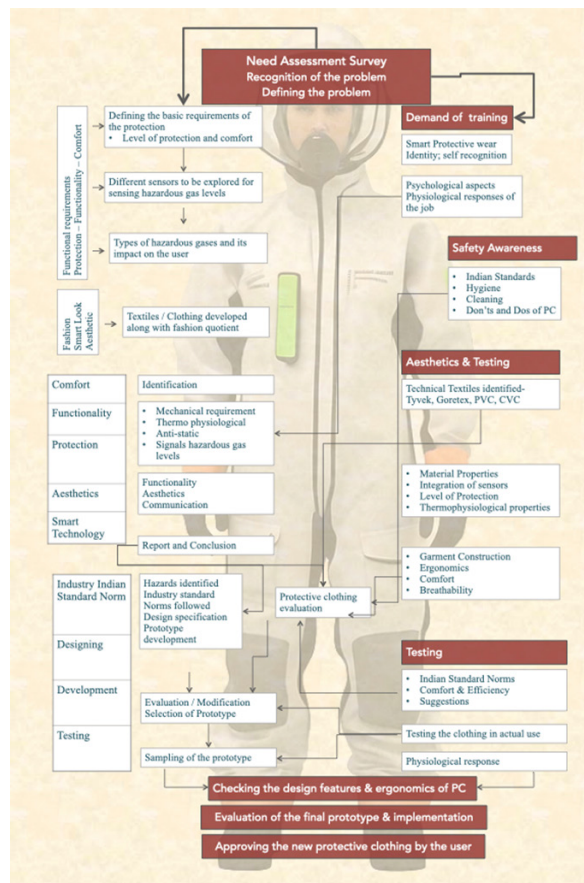


Figure 3: Conceptual Design Framework for designing protective clothing for sewage cleaners

common response across the responses that was observed was that the existing design solutions are not user centred and lack the empathetic understanding of their needs. Out of the 30 respondents 87% respondents were males (figure 4) with majority of them under the age of 40 years (figure 5).

The interviews with the respondents and the respondents sharing their dreadful experiences emphasised on the need for the authors to provide dignified design solutions with safety assurance. The respondents mentioned that there is a better awareness compared to a decade ago, however still the present protective wear does not have any indication or warning about when they are exposed to hazardous gas levels that can be life threatening. The idea of integration of sensors that can alert the wearer and supervisors was welcomed by each of the

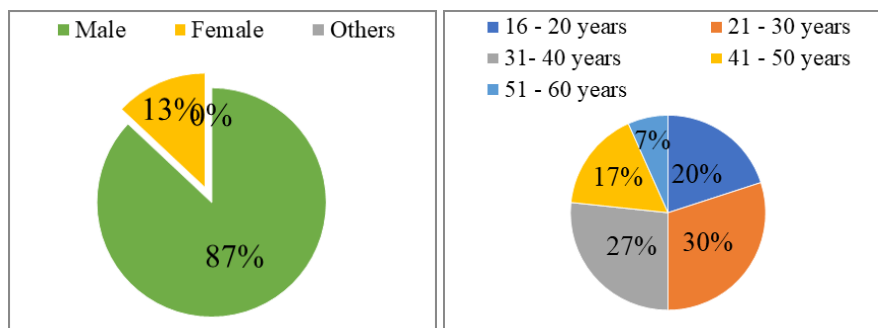


Figure 4: Gender Distribution; Figure 5: Age distribution

respondents. The focus was also on high visibility and scope for light attachment as they often need to work in low visibility septic tanks and sewers.



### 4.3 DESIGN IDEATION

The review of literature and the interviews with various researchers from CIRCOT Mumbai and scientists working on developing Internet of Things (IoT) and sensors to understand the material identification and sensors to develop the right design solution for the sanitation workers. Based on the conceptual framework and the review of literature, the authors also developed a design framework to have a better understanding of the design considerations to be kept while designing a smart protective clothing (figure 6). This framework specifies the need to address the features of easy don and doff, comfort, real time monitoring, high visibility as well as the right integration of wearable technology. The authors as designers propose a protective clothing developed using Tyvek with high visibility reflective tapes incorporating existing sensors. The identified sensors developed as a research by an institute in Hyderabad look at monitoring the body temperature, heart rate and the hazardous gas levels. The proposed IoT system will be integrated in the designed. Figure 7 showcases a rendered sketch of the designs proposed as a result of the study conducted. The use of reflective tapes for high visibility and LCD display for alerting the alarming gas levels to the wearer and his peers while sending the signal to through the connected mobile application to the supervisors aim to provide timely help for the sanitation workers. The proposed design

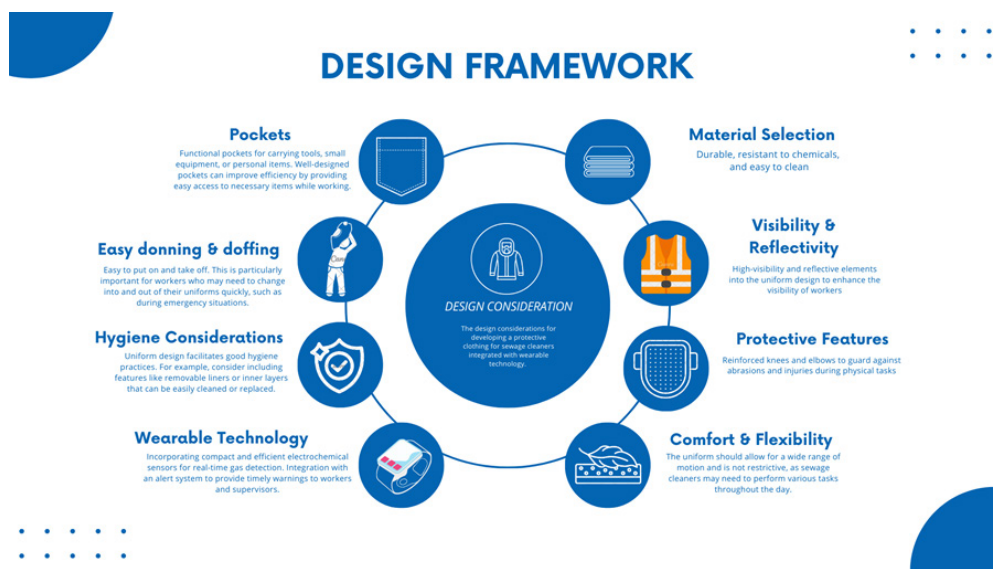


Figure 6: Design framework for key design considerations

has padded knee support as the workers often have to crawl on the knees to move across the sewers and septic tanks for carrying out their job work. The protective clothing comes with rubber gloves and boots for better hand and foot protection. The coverall also comes with



Figure 7: Proposed designs with LCD display connected to sensors, high visibility and padded knee guards



Figure 8: Proposed designs with sensors, high visibility and multifunctional pockets

head protection and gas mask to avoid inhaling hazardous gases. The sensors monitoring body temperature, heart rate as well as the gas levels are placed inside the top chest pocket for better sensitivity towards data collection. Further due to ensuring better protection against the unhygienic surroundings as well as hazardous levels, taped and double taped seam constructions are proposed by the authors for the process of manufacturing the designed protective clothing. The designs were presented to the stakeholders (n=30) for their feedback and were evaluated for the parameters of functionality and aesthetics on Likert scale for upper and lower garments. The figure 9 shows the results of the feedback received from the stakeholders for the same. Overall the designs were very well received by the stakeholders.

## 5. CONCLUSION:

This developmental paper outlines a comprehensive design framework (figure 3) and approach for developing smart wearable protective gear for sewage cleaners in India. By



Figure 9: Chart presenting the Likert scale evaluation of functional and aesthetic parameter of the designs

addressing the limitations of existing protective clothing, incorporating advanced technologies, and considering the unique challenges faced by sanitation workers, the proposed design aims to provide better living and working conditions. As we move towards a future where technology contributes to societal well-being, the integration of wearables in protective clothing emerges as a crucial step in uplifting marginalized communities. In the words of Albert Einstein, "Strive not to be a success, but rather to be of value." This research aspires to be of value by contributing to the safety, dignity, and well-being of sewage cleaners, who play an indispensable role in the sanitation infrastructure of our society.

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