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Research Article

Enhancing Safety in the Chemical, Petrochemical, and Ink Industries Through Smart Barcoding Systems: A New Era of Immediate MSDS Accessibility and Risk Reduction

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Abstract

In the chemical, petrochemical, and ink industries, the safe handling, transportation, and disposal of chemical containers are critical to protecting human health and the environment. Traditionally, access to Material Safety Data Sheets (MSDS) — essential documents detailing hazard information and handling instructions is often delayed, as end users must request them from manufacturers, a process that can take several days or even weeks. This delay poses significant safety risks, especially for workers involved in chemical use, container scraping, and recycling who may not have immediate access to hazard information.

This review proposes the integration of smart barcoding systems directly on chemical container labels, linking instantly to MSDS and safety instructions. Such innovation would drastically reduce response time, enhance user awareness, and promote compliance. Furthermore, this paper advocates for MSDS availability in local languages, ensuring that all stakeholders — including less-educated scrap handlers and recyclers — fully understand the risks and necessary precautions.

By leveraging modern technology, industries can foster a new safety culture, minimize accidents during handling and recycling, and align with global regulatory expectations. This paradigm shift has the potential to set new safety standards across the chemical lifecycle.

Keywords: Environmental Impact; Health Hazards; Material Safety Data Sheets (MSDS)

Introduction

The chemical, petrochemical, and ink industries are indispensable to the global economy. They provide essential raw materials and products for a wide range of sectors, fuelling manufacturing, agriculture, construction, and numerous other industries [1]. The chemical, petrochemical, and ink industries are vital to numerous supply chains globally. However, these industries followed regulations during the shipment to avoid significant risks due to the nature of the materials involved. These materials often exhibit hazardous properties such as flammability, toxicity, and corrosivity, which can lead to accidents, environmental damage, and health hazards if not properly managed. Traditional safety practices, which rely heavily on manual processes and paper-based documentation, are often inadequate to address these challenges effectively [2,3].

While the chemical, petrochemical, and ink industries are crucial drivers of the global economy, their operations raise significant concerns regarding safety, health, and environmental protection. Addressing these concerns through stringent regulations, technological advancements, and a commitment to sustainability is essential to ensure the long-term viability of these industries and the well-being of people and the planet. Safety, Health, and Environmental Concerns:

- **Environmental Impact:** The production, use, and disposal of chemicals can have significant environmental consequences. These include air and water pollution, soil contamination, and the release of greenhouse gases, contributing to climate change [2,4]
- **Health Hazards:** Workers in these industries and communities living near production facilities may face health risks due to exposure to hazardous chemicals. These risks range from acute effects like skin irritation and respiratory problems to chronic conditions such as cancer and neurological disorders[1-2].
- **Safety Risks:** The industries involve the handling of flammable, corrosive, and toxic materials, posing significant safety risks. Accidents such as fires, explosions, and chemical spills can lead to injuries, fatalities, and environmental disasters [1,3].
- **Regulatory Measures:** Governments and international organizations have implemented regulations and standards to mitigate the negative impacts of these industries on health, safety, and the environment. These include pollution control measures, safety protocols, and restrictions on the use of certain hazardous chemicals.
- **Sustainability Efforts:** The industries are increasingly focusing on sustainability to address these concerns. This includes developing green chemistry practices, promoting recycling and circular economy approaches, and investing in cleaner production technologies [5,6].

Major chemical accidents in last 10 years

Over the last decade, India has witnessed several major accidents in the chemical, petrochemical, and oil & gas sectors during transportation, disposal, and recycling operations. Critical incidents include the Visakhapatnam gas leak (2020), which affected over 1,000 people due to a styrene leak, and the Dahej chemical explosion (2020) that resulted in 5 deaths due to a suspected gas leak. Similarly, a tragic factory fire in Hapur (2022) claimed 12 lives, highlighting safety lapses in illegal chemical operations. Transportation hazards were evident in the Nashik oil tanker explosion (2018), causing fatalities due to leakage and ignition of flammable materials. In the domain of waste management, illegal chemical waste dumping in Unnao (2015) led to groundwater contamination, endangering community health.

In industries dealing with chemicals, petrochemicals, and inks, safety data and regulatory compliance are essential components of operational responsibility. Access to Material Safety Data Sheets (MSDS), which provide crucial information on handling, storage, and disposal of chemical products, is often delayed due to traditional communication chains between users and manufacturers.

This delay, spanning several days to even weeks, can increase the risk of mishandling and workplace accidents. There is an urgent need to modernize and digitize safety practices to ensure immediate access to critical information.

MSDS a way for Chemical hazard communication

A Material Safety Data Sheet (MSDS) commonly referred to as a Safety Data Sheet (SDS) is an essential document that provides detailed information on the properties, hazards, and safe handling of a chemical product [1,6]. It informs employers and workers about chemical risks and outlines steps for safe usage, storage, disposal, and emergency response. Each MSDS typically includes:

- Section 1: Identification
- Section 2: Hazard(s) Identification
- Section 3: Composition or ingredients
- Section 4: First-Aid Measures
- Section 5: Fire-Fighting Measures
- Section 6: Accidental Release Measures
- Section 7: Handling and Storage
- Section 8: Exposure Controls/Personal Protection
- Section 9: Physical and Chemical Properties
- Section 10: Stability and Reactivity
- Section 11: Toxicological Information
- Section 12: Ecological Information
- Section 13: Disposal Considerations
- Section 14: Transport Information
- Section 15: Regulatory Information
- Section 16: Other Information (GHS, 2023)

Regulatory agencies governing MSDS/SDS

The preparation, distribution, and maintenance of MSDSs are governed by several agencies worldwide:

- **OSHA (Occupational Safety and Health Administration, USA):** Under the Hazard Communication Standard (HCS) (29 CFR 1910.1200), manufacturers must provide MSDSs/SDSs for hazardous chemicals [1,2,7]
- **REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals, European Union):** REACH mandates that suppliers provide SDSs for hazardous substances [4].
- **GHS (Globally Harmonized System of Classification and Labelling of Chemicals, United Nations):** GHS standardizes SDS formats globally into 16 sections [8-10].
- **EPA (Environmental Protection Agency, USA):** Requires chemical hazard communication, including MSDSs, under environmental protection regulations [5-7].
- **CPCB (Central Pollution Control Board, India):** Enforces environmental regulations requiring MSDSs for chemical manufacturing and waste management [8-11].
- **DGFT and MOEFCC (India):** Govern chemical imports/exports and hazardous waste handling with MSDS requirements [12-14].

Main aim of an MSDS

The primary objective of an MSDS is to communicate critical chemical hazard information to ensure:

- **Worker safety**: Providing necessary information to prevent health risks [1].
- **Emergency preparedness**: Supporting quick and safe response during accidents [1,5,9].
- **Environmental safety**: Promoting safe chemical disposal and minimizing ecological damage [4,5]
- **Regulatory compliance**: Enabling organizations to meet national and international chemical safety laws [5].

End-User consultation of MSDS

Studies show that many end users, including chemists and recyclers, do not consistently refer to Material Safety Data Sheets (MSDS) before using chemicals or handling empty containers. According to a survey published in the International Journal of Environmental Research and Public Health, even among well-educated consumers, awareness and understanding of chemical hazards are significantly low [15].

Furthermore, a study on the readability and comprehension of SDS (Safety Data Sheets) indicates that many sheets are written in complex technical language, making it difficult for general users to understand them [13]. Another article from Safety and Health Magazine emphasizes that without proper training, users find it hard to effectively interpret MSDS, even when they have access to them [14,15]. Thus, lack of awareness, complicated documentation, and poor training are major reasons why MSDS documents are underutilized by end-users.

Current scenario in MSDS procurement

In the chemical, petrochemical, oil and gas, and related industries, Material Safety Data Sheets (MSDS) are critical documents that provide information about a product's hazards, safe handling, storage, and emergency measures.

Currently, the process usually happens like this:

- **Product Purchase**: When an end user purchases a chemical, the supplier may provide an MSDS along with the shipment. However, this is not always automatic — often the shipment includes only the chemical product with basic labelling.
- **MSDS Request:** If the MSDS is not included, the end user must manually request the MSDS from the manufacturer, supplier, or distributor.
  - This request can happen through email, official website forms, or by calling customer service.
  - Time Delays: It often takes several days to weeks for the end user to receive the correct MSDS, depending on the company's responsiveness and internal processes.
- **Access through Company Websites:** Some global companies (especially in Europe, USA) have started uploading MSDS databases on their websites where users can search by product name or code. However:
  - This is less common in India and developing markets.
  - Sometimes documents are outdated or hard to locate without proper batch information.

- **Compliance Gap:** Not all manufacturers consistently update or provide MSDS documents easily.
    - Some users end up using hazardous chemicals without reading the updated safety instructions, which is a major compliance and safety risk.

Table 1: How End Users Currently Get the MSDS.

Steps	Action	Issue
1	End user contacts supplier or manufacturer by email or call	Time-consuming
2	End user checks the company's website for MSDS download	Not always available; version mismatch
3	End user waits for manual sharing via email	Risk of delay
4	Sometimes gets MSDS only after escalation or multiple follow-ups	Operational risk

The lifecycle of a chemical container

The lifecycle of a chemical container encompasses several critical stages: filling with chemicals, usage, storage, emptying, and final recycling. Adhering to global Standard Operating Procedures (SOPs) at each stage ensures safety, environmental protection, and regulatory compliance. Below is an overview of each phase, along with associated best practices and references.

- Filling and Labelling
- Storage of Filled Containers
- Usage and Handling
- Emptying and Decontamination
- Recycling or Disposal

Proposed solution-smart barcoding system

Barcodes on the label for immediate MSDS accessibility

The introduction of dynamic barcodes on each product container or packaging label is a powerful step forward. These barcodes, when scanned via a smartphone or a dedicated scanner, would redirect users to a live, always-updated MSDS and other safety instructions.

Key advantages of this system include:

- Instant access to critical information without waiting for manual sharing.
- Reduced administrative workload for manufacturers and distributors.
- Real-time compliance with global safety standards.
- Dynamic updates: If the MSDS is revised due to regulatory changes, the link can be updated without reprinting labels.

By implementing barcodes on all chemical containers, every user, including field operators, warehouse staff, and end customers, can be empowered to make safer, informed decisions immediately upon receipt of the material.

MSDS in Local Languages: Enhancing safety for scraping and recycling

Traditionally, Material Safety Data Sheets (MSDS) are provided only in English, which may be sufficient for chemists, regulatory staff, and educated industrial users. However, this creates a major gap when the product or its empty containers reach scrapers, recyclers, or ground-level handlers, many of whom may not be proficient in English.

Problem

During scraping, recycling, or disposal, improper handling due to lack of understanding of hazards (flammability, toxicity, environmental risks) can lead to serious accidents, contamination, or fatalities.

Current risk

Scrapers and recyclers often rely only on symbols (e.g., flammable, toxic signs) without truly understanding the precautions, first-aid measures, or disposal methods.

In addition to the barcode system linking to MSDS:

- The MSDS should be translated into local/regional languages (such as Hindi, Tamil, Telugu, Bengali, Marathi, etc.).
- Multi-language MSDS versions should be made available automatically through barcode scanning.

- Key sections like "Hazards Identification", "First Aid", and "Handling and Storage" must be simplified and highlighted in local language for immediate understanding.

Advantages

- Makes safety accessible to all levels of workers.
- Reduces accidents during recycling, disposal, and transportation.
- Improves regulatory compliance under global standards like GHS (Globally Harmonized System) which recommends multi-language labelling.
- Builds corporate social responsibility (CSR) for manufacturers.

Application during product disposal and recycling

Post-use safety is an often-overlooked aspect of chemical product handling. After the contents of a container are emptied, the residual material and container itself can still pose hazards. Currently, many disposal personnel may not have access to MSDS when managing empty drums, buckets, or barrels.

Embedding a permanent barcode on the container's label ensures that even during scraping, recycling, or waste handling, workers can easily scan and access:

- Disposal guidelines
- Residual hazard information
- Personal Protective Equipment (PPE) requirements
- Emergency measures in case of spills or accidents

This practice significantly lowers the risk of exposure, prevents accidents, and ensures environmental compliance during disposal and recycling operations.

Impact on safety and compliance

Adopting barcode-enabled safety systems could lead to:

- Faster hazard communication, leading to a reduction in workplace accidents.
- Higher regulatory compliance, especially for international shipments.
- Improved environmental stewardship by ensuring responsible disposal practices.
- Enhanced trust and transparency between manufacturers, end users, and regulatory authorities.

It can also support internal audits, OSHA inspections, and ISO certifications by demonstrating proactive risk management measures.

Figure 1 Example of a Product Label with Barcode Linking to MSDS. This figure illustrates a typical chemical product label featuring a barcode (QR code or 2D code) linked directly to the product's Material Safety Data Sheet (MSDS). The label includes essential elements such as the product name, hazard symbols, handling instructions, and batch information. The barcode is strategically placed on the label to provide immediate digital access to safety information, helping ensure safe handling, storage, transportation, and disposal of the product.

Figure 1: An example of product's label with a barcode of MSDS.

Steps to Scan the Barcode and Access MSDS:

- **Open a QR code scanner app**: Use your smartphone camera or any free QR code reader app (available on Android and iOS).
- **Point your camera at the barcode**: Align the barcode within the scanning frame. The scanner will detect and read it automatically.
- **Click the link**: A secure web link will appear on your screen. Tap it to open.
- **View or download the MSDS**: The linked page will display the MSDS in PDF or web format. You can read it online or download it for offline access.

Conclusion

The integration of barcode technology into chemical, petrochemical, and ink industry safety protocols represents a smart, scalable, and immediate solution to longstanding challenges in hazard communication and regulatory compliance. By bringing MSDS access to the fingertips of every handler and worker, industries can create a safer workplace, foster a culture of awareness, and reduce environmental risks.

This simple yet powerful change has the potential to transform safety practices across the globe. Regulatory bodies, manufacturers, and industry stakeholders must collaborate to drive adoption for the well-being of both workers and the environment.

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