Waste 4.0: Towards Digitalization in Waste Management Segregation

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Medical Waste Categorization

**Sharps**: needles, syringes, scalpel, knives

**Infectious waste**: waste contains pathogens, contaminated with blood or body fluid, infectious with patient diseases

**Pathological waste**: human organs, body parts and tissues

**Chemical waste**: laboratory reagents, disinfectants, solvents

**Pharmaceutical waste**: expired pharmaceuticals, cytotoxic contains genotoxic

**Radioactive waste**: unused liquid for radiotherapy or laboratory research, contaminated glassware

**General waste**
Medical Waste Challenges

Problem

- Ineffective colour coded system
- Generation amount of medical waste
- Non-specific categorization in digitalization
- Manual management in medical waste procedures
Medical waste challenges

1. The current system of color-coded bins is ineffective in monitoring the waste condition.

- Injuries during handling
- Virus spread through waste
- Misuse and fraud
Medical Waste Issues

2. The generation of medical waste increasing over the years.

REPORTED MEDICAL WASTE TONNAGE IN UK

<table>
<thead>
<tr>
<th>Year</th>
<th>Tonnage (ton.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019/2020</td>
<td>150852</td>
</tr>
<tr>
<td>2020/2021</td>
<td>161449.87</td>
</tr>
<tr>
<td>2021/2022</td>
<td>176833.11</td>
</tr>
</tbody>
</table>
Medical Waste Issues


- **Segregation**
  - Segregate and Collect Waste
    - Correct categories and labeled by colour-coded bins.

- **Storage**
  - Storage facilities
    - Well-maintained, adequate light and ventilation, and free from pests.
    - Follow regulations of waste storage time.

- **Transport**
  - Transport wastes from storage to process facilities
    - Avoid populated areas, water catchments, and other environmentally sensitive areas.

- **Process**
  - Treatment and Disposal Process
    - Aim to reduce the potential of infection, contamination or virus spread to humans and the environment.
Medical Waste Issues


<table>
<thead>
<tr>
<th>Research</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shirke, S.I. et al. (2019)</td>
<td>Separation by moisture</td>
</tr>
<tr>
<td>Sen Gupta, Y. et al. (2021)</td>
<td></td>
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<tr>
<td>Das, A. et al. (2021)</td>
<td></td>
</tr>
<tr>
<td>Wang, H. et al. (2022)</td>
<td>QR code tagging</td>
</tr>
<tr>
<td>Sri Suvetha, C. et al. (2022)</td>
<td>360 camera image processing of 4 groups of waste</td>
</tr>
</tbody>
</table>
Research Questions

What is the importance of waste segregation in the healthcare industry?

How is the current method used in monitoring waste segregation?

How can digitalisation help make adequate waste segregation and benefit the monitoring system as a whole?
# Current Monitoring Methodology

<table>
<thead>
<tr>
<th>Category</th>
<th>Colour code</th>
<th>Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sharps</td>
<td>Yellow</td>
<td>marked ‘SHARP’ with a biohazard symbol</td>
</tr>
<tr>
<td>Infectious Waste</td>
<td>Yellow</td>
<td>Biohazard symbol</td>
</tr>
<tr>
<td>Pathological</td>
<td>Yellow</td>
<td>Biohazard symbol</td>
</tr>
<tr>
<td>Pharmaceutical and Genotoxic</td>
<td>Brown</td>
<td>Hazard symbol</td>
</tr>
<tr>
<td>Chemical Waste</td>
<td>Brown</td>
<td>Hazard symbol</td>
</tr>
<tr>
<td>Radioactive waste</td>
<td>-</td>
<td>Radioactive symbol</td>
</tr>
<tr>
<td>General waste</td>
<td>Black</td>
<td>General waste</td>
</tr>
</tbody>
</table>
Aim

To propose a recommended method to digitalise the segregation of medical waste in hospitals.
Objective

1. To capture current approaches of medical waste segregation via a structured literature review.
2. To find a method to segregate the waste digitally without human intervention.
Research Method

1. Literature Review – How current approach of waste segregation
2. Analyse challenges of current approach
3. Review digital technology used in Waste Management
4. Review proposed digital technology
5. Design framework of medical waste segregation
Proposed Methodology

**Perception layer**
- RFID as data transporter
- Scanner to scan RFID

**Network layer**
- WiFi to connect to cloud storage
- Cloud to store and analyse data

**Application**
- Status of waste segregation in the bin
- Notification to waste generator
Proposed Methodology

All medical equipment, tools, and hazard bags are tagged with RFID coded by the segregation groups.

The scanner on the waste bin scans to ensure all the wastes are in the same category.

Send the data to the systems

Notify waste generator to re-segregate

Yes

mixing of waste

No

Record to the mobile application and ready for a collection
Proposed Method
Proposed Method

**Manufacturing Factory**
- RFID plant to every unit of medical tools, equipment, and PPE.

**Segregation**
- Waste bins
- RFID reader to control violation.

**Storage**
- Storage facility
- Durative sensor for inventory administration.
- Humidity sensor to control waste condition.

**Transport**
- Transporting Truck
- RFID Reader to record travel and handling company information.

**Process**
- Process / Disposal Facility
- RFID Reader to record facility location and the process taken to the waste.
- Temperature sensor to monitor process temperature.

**Process / Disposal Facility**

**Manufacturer** ➔ **Hospital** ➔ **Contractor** ➔ **Occupier**
Research Impact

• Decrease human intervention and injuries in waste management
• Decrease amount of hazardous waste
• Promote recycling
Digitalization of segregation will smooth the waste management procedures, generate real-time data that can be easily shared, reduce the amount of hazardous waste, and promote more recycles of waste from the healthcare industry