Smart Waste Management for Smart City: Impact on Industrialization

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Abstract. Waste in different forms such as solid waste, gaseous waste and liquid waste increases due to population increase, urbanization, and industrialization and affect the globe. Waste management involves activities such as reuse, recycling and reduces waste generation and other strategies to combat the effect of waste generation due to increasing population and industrialization. Monitoring is one of the key functions of waste management, as it is needed to address the issues faced by waste management, which includes waste generation, waste collection, transportation of waste, waste treatment and waste disposal processes. This paper reviewed the technology involved in achieving a smart management and suggests the use of artificial intelligence (AI) to solve waste management such as convolutional neural network for efficient classification and waste identification and other AI technology.

Key words: Waste, Waste Management, Smart Management Technology, Smart cities

1. Introduction

The development of a Sustainable environment and economy has been the need of our society today [1]. Waste in different forms such as solid waste, gaseous waste and liquid waste increases due to population increase, urbanization, and industrialization and affect the globe. Greenhouse gas emissions, air pollution, soil pollution, and water pollution are common problems related to improper waste disposal [2]; [3]. The assumption by [4] that in 2025, the population of the world will be about 8 billion. This will result in a rapid waste generation, as the population will be concentrated in the urban region. Materials such as paper, organic materials, plastics, and food are the main constituent in waste [5]. Waste generation as much as it is growing directly affects humans as waste is health risk affirmed by [6], break out in diseases such as malaria, asthma, gastrointestinal disorders, bronchitis, and other diseases are experienced by people living with or around waste dumps. Another impact of waste on human health can lead to death as reported by [7], the report shows 8 death which was associated with air pollution from waste as harmful gases can be produced with an accumulation of various waste in waste yards or landfill [8]. Greenhouse gases emission such as CO₂ that is emitted abundantly due to combustion, CH₄ is heat-trapped gas and is emitted with a change in temperatures such as climate change, N₂O, and F-gases as illustrated by [9]; [10]. Waste in many forms is the contributory factor to climate change that is an issue in our present society and the increased emission of some gases such as CO₂, which is increasingly, emitted (United Nations, 2019). Also, in health institutions including laboratory, health care centers and facilities and medical research centers, medical waste is generated which can be toxic or infectious [11]. The amount of waste generated depends on the population factor. The increasing population according to [12], [13] discussed waste generation with respect to the development of counties, the research revealed the percentage of the global waste generation with respect to developed, developing and under-developed countries as shown in the figure below, the developed countries have the higher tendency to generate waste greater amount of waste followed by the developing countries then the underdeveloped countries generate lower amount of waste with a ratio of
40%, 37% and 23% respectively. Concurring with [13] have portrayed that the amount of refuse is associated with the standard of living and per capita income

![Pie chart showing waste generation with respect to development](image)

Figure 1. Waste generation with respect to development [13].

In developing countries like Nigeria, waste generation is not just the issue faced concerning waste. [14] discussed on other factors, which are linked to waste generation such as improper disposal method, poor waste maintenance, and insufficient waste maintenance facilities. Vital impact on urbanization through smart technology has influenced all sectors directly, where smart technology is a part of the system, and indirectly, where the system can function on its own but with a better output with smart technology. Today’s cities which are driven towards the incorporation of smart technology and management to achieve a smart city in order to improve health and access to health care, education, security, and other living conditions in a more effective and stress-free manner. The development of smart cities, smart technology, and smart management prompt researchers to investigate possible ways to fuse smart technology while making smart management decisions on issues in a city to make it a smart city. The paper’s focus, which is a municipal waste, limits the scope of the research to waste generated in smart cities. Hence, the intervention of smart technology, ICT, and smart strategies in waste management is needed for the proper management of waste.

2. Waste management, Characterization and Treatment

Waste management involves activities such as reuse, recycling and reduces waste generation [15] and other strategies to combat the effect of waste generation due to increasing population and industrialization. Monitoring is one of the key functions of waste management, as it is needed to address the issues faced by waste management, which includes waste generation, waste collection, transportation of waste, waste treatment and waste disposal processes. The characterization of waste is an important step to effective waste management to achieve zero waste. Recent research on smart approach to waste management boiled down to achieve Zero waste, which is driven toward conserving raw materials and resources, and reducing municipal waste issues in smart cities. These issues, including production of harmful gaseous and air pollution through incineration, and land pollution and contamination leading to a breakout of disease thought landfilling by reusing, recycling, composting waste and minimization of waste [16]; [17].

Research by [16] elucidated the importance of waste characterization in achieving zero waste routing through the essence of considering the carbon to nitrogen concentration ratio in the production of
composite from organic waste materials. In another research by [18], concurring to the need for waste characterization, called attention to the need to characterize plastics wastes in terms of waste product life cycle, quality, product application, presence of impurity which can occur in forms of various plastic colour, bi or multi polymer waste material and plastic offsets, and polymer set. [19]characterized and identified organic materials, paper, and plastic as airplane cabin waste.

Various research on waste treatment has opens doors to various methods of treating waste. The table below segmented various waste and the waste treatment associated to the waste as proposed by the author. In a study by[20], it was highlighted that waste are no longer just garbage but are recoverable resources harnessed through adequate waste treatment and the Commonly used methods for waste treatment involves sanity landfill, incineration and pyrolysis-gasification, other methods exist.

| Waste materials      | Treatment approach                                      | Source                          |
|----------------------|--------------------------------------------------------|---------------------------------|
| CO₂                  | Amine-based carbon dioxide capture using an Amine based PCC plant. | (Ghayur et al. 2019)            |
| Health care waste    | Thermal plasma technology                               | (Gomez et al. 2009)             |
| Organic liquid waste | Thermal plasma technology                               | (Li et al. 2016)                |
| Slag                 | Removal of phosphorus in wastewater using Steel slag    | (Roychandet al. 2020)           |
| Wastewater           | Membrane bioreactors technology                         | (Zandi et al. 2019)             |
| Industrial biowastes | Membrane bioreactors technology                         |                                 |
| Material waste       | Thermal oxidation method                                | (Caraccio et al. 2013)          |
| Human waste          |                                                         |                                 |
| Organic waste        |                                                         |                                 |
| Plastic waste        | Co-pyrolysis/gasification                               | (Chai et al. 2019)              |
| Biomass waste        |                                                         |                                 |
| Waste tires           | Pyrolysis and gasification experiment                    | (Ongen et al. 2019)             |

3. **Smart Waste Management**

Utilization of automation in automated systems serves several advantages such as improved productivity, reduces time and resource utilization, increased efficiency over manual system[21]. Most smart waste management process adapts some processes of the traditional waste management but includes innovation and new technology in performing its action[22]; [23]. Smart waste management involves an innovative approach that involves the use of information and communication technology (ICT) to making strategic decisions with respect to waste characterization, waste generation, waste collection, transportation of waste, waste treatment and waste disposal processes. Combating the waste issues due to development, a large amount of data is involved because of this automated data acquisition, communication, identification, and storage, are used for easier analysis [24]; [25]. Several sensor technologies today are embedded into waste management systems such as infrared sensors, metal detectors and odor receptors for
monitoring. The classification of new technology in various waste management area addressed by information and communication technology involves spatial technology for waste collection vehicle and bins location monitoring, identification technology for bin location and to identify the time for collection, Data acquisition technology which involves sensor technology. Sensor technology employs the use of sensory materials and devices in order to obtain the status of the bin, and finally the data communication technology for the transfer of information or data for analysis and is used in other systems[25].

**Spatial technology**

Spatial analysis is a major focus with respect to environmental studies hence plays a vital role in environmental modelling. Capturing, storing, spatial data analysis and data mapping. Spatial data consists mainly of spatial topology, raster, attribute data, and features.

- geographic information systems (GIS)
- global positioning system (GPS)
- remote sensing (RS)

GIS is an information system with functions such as data collection, data storage, data analysis, data integration, data manipulation, and data display.[24] classified GIS using four categories through the process of operation in GIS, which involves generation of data, data management, cartography, and data analysis. GPS is a global navigation and positioning system for location based on a well-arranged multiple satellite and ground stations. The sensing technology from satellites for the detection and classification of an object from a remote platform through signal propagation is done by remote sensing. It consists mainly of sensors, image processing tools and data communication tools [24].

**Data acqisition/ Sensor Technology**

The study of the behavior of an object while reacting with an external environment is harnessed by the internet of things while it is applicable in one or two aspects of our day. Most sectors have adapted the internet of things by incorporating its internet of things as part of their system such as in healthcare, industry, smart cities, agriculture, etc. [25].

**Identification technology**

[26], identified barcode and RFID technology as types of identification technology for solid waste management. The use of radio signal for identifying data is ascribed to RFID technology consisting of microchips, a coiled antenna and a reader (Radio frequency identification (RFID) in hospitality).

Recent research in the area of environmental safety is aimed at better ways to address the issues using technology owing that technology offers a better approach in solving waste and waste management problems. In [27], the author provided an approach to automatically control waste using an automated waste control management system (AWCMS). Fig 2 shows the flowchart of [27] contribution to automated waste management. The waste in the bin is detected using an infrared sensor, performs location identification using GPS, Arduino board (for its microcontroller) and GSM module to send information on the level of waste in the waste bin.

[28] proposed an easier and low-cost approach of using internet of things to manage waste. The author introduced the “intelligent receptacle” which is a wireless monitor for garbage bin that can detect the level of bin and send a message when the bin is full. Fig 3 shows the flowchart from input of user ID to END. [29] developed a GSM based Garbage Monitoring System for smart garbage management purposes mainly to monitor the garbage level to prevent overflow using infrared sensor, communicate this information using GSM system, and fire alert system. A microcontroller interfaces these systems.
4. Conclusion

Satisfying the area of environmental safety, in-depth understanding on factor is considered while making decisions with respect to how best to manage waste. Waste generated in smart cities is a category of municipal waste. Traditional approach in solving waste management issues have failed as it is not reliable or sustainable as it takes a lot of input to have little or no work output. The increase in population, urbanization and industrialization have increased waste generation in an alarming rate, hence traditional approach is not able to properly collect and analyses the data from waste dumps. The infusion of technology to waste management practices involving sensing provides a smart to solve waste issues. Various authors have investigated various innovative approach to improve waste management hence improving some technology in existence such as spatial technology, data acquisition technology and identification technology. Most researcher have not ventured in the area of artificial intelligence where machine learning and deep learning is used to achieve a better insight on the waste and provides a better analysis for taking strategy. Machine learning involves learning without being explicitly programmed by training the system with a set of training data. Machine learning algorithms has the capacity to train using data sets from acquired using from the spatial technology, data acquisition technology and identification technology. Naïve Bayes classification, Linear regression, Logistic regression, Support vector machine (SVM), Decision tree and K-means clustering are machine learning algorithm and are applicable in waste management. In addition to the use of machine learning approach, convolutional neural network (CNN), a neural network for tracking, image and object detection. CNN consisting of input acquired from sensing to have a visual representation of image after that, it goes through series of hidden layers where the input is more understood, finally the output. A more critical analysis of waste data is assured in a short time with
the best possible output thereby ensuring a better output. Therefore, research on application of artificial intelligence tool with already existing technology to perform waste management processes.

Figure 3. IOT Based E-Tracking System Flowchart (Gokhale et al., 2018)

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