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Role of Modern Technologies and Internet of Things in the Field of Solid Waste Management

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Abstract

The process of handling solid waste becomes complex and tedious due to the urbanization and industrialization of the most developing and developed countries. These solid waste issues if it is not addressed properly it affects ecosystem and environment. There is a possibility of many health-oriented issues especially during the pandemic period covid-19. Most of the human beings are struggling with respiratory pulmonary diseases, asthma caused by these solid wastes. Most of the governments are also spending huge amount of money for labors, devices and some technologies to tackle these solid waste issues. There is also an opportunity for the government to generate revenue from these solid wastes by properly sorting these waste into recyclable, non-recyclable and bio-degradable wastes. But when humans are involved in sorting these waste it will cause some diseases and hygienic problems. So,in order to address the above said issues in this work the role of modern technologies, algorithms and some Internet of things (IoT) methods are discussed. Implementing these technologies in the future will save huge amount of money spent by the government for the solid waste management activities.

Keywords: environment, pandemic period, diseases, technologies, internet of things.

1 Introduction

The recent survey conducted by the world bank predicts that solid waste generation would rise up to 2.3 billion by 2025. Waste management is serious problem to both the developed and developing

nation. Improper waste management will lead to much health-related breathing diseases like asthma and Chronic Obstructive Pulmonary Disease. People who are residing near the garbage area will be affected by dengue, viral fever and other fatal diseases. More than 230 million people become the victim for inhalation problems due to air pollution. The proper waste management just assures the health of the aspirants residing near the garbage. But most of the waste which are landfilled will affect the ecosystem and it becomes a big threat to the environment and cultivation. In India there is no cost-effective waste segregated approach at each individual house which is the high demand at this time for effective waste management.

Industries are planning for zero waste goal but they are able to reduce only 70% of the waste collected. If the plastics are properly recycled instead of landfilling 60 Tonnes of oil barrel could be produced. This paper reviews two major waste management system in house hold; one is biological method and other one is physiochemical method. Also, they conclude that waste management for domestic use will reduce the amount of solid waste for transportation and collection work [23] but there are some barriers in handling the recycling activities 1) laws and regulations framed by the government and budget allocated for recycling activities. 2) most of the peoples are unaware of the self-recycling. 3) There is no proper recycling technology 4) Expenses in waste management[20]. In order to address this issue, it is necessary to sort these wastes into recyclable, non-recyclable and bio-degradable wastes. which will include all the solid wastes ranging from paper, plastic, rubber, sheet metal, glass etc., there are two types of possible errors in sorting one is not identifying the correct object and the second one is placing one category over the other. also sorting by the humans are non-hygienic so some robots with picking arm and artificial intelligence concepts are used for sorting the wastes.Revenue generation by sorting the recyclable waste will increase through artificial intelligence and automation methods. When the automation is combined with recycling work with the back support of artificial intelligence recycling task gets smarter day to day.

2 Role of IoT,Modern technologies, optimization techniques, and of Radio Frequency Identification (RFID) in solid waste management

This paper discusses about the following;
1. Part of IoT in in solid waste management
2. Part of modern technologies
3. Use of optimization techniques and algorithms
4. Part of Radio Frequency Identification (RFID) in solid waste management

2.1 Part of IoT in in solid waste management

Reduction of waste by adopting modern industrial automation techniques in waste management was carried out. To improve performance of the solid waste management process there are various technologies like artificial intelligence, IoT (internet of things), automation, were well planned and implemented. The objective here is to combining the smart cities with the aid of IoT, collecting data and analyzing the data using Big Data, Data Analytics concepts. By this modern technology introduction, waste processing of any part of the geographical area could be assessed easily. When the trash is coupled with IoT used to identify the trash volume by the servers. Data collected in the waste management is given as input for the Graph theory optimization and other related algorithms combined to form efficient waste management system [16]. Sensors are used to identify the trash volume which helps to prevent the overflow of trash bins. Once the sensors give the signal of trash overflow level it will be cleaned immediately on the routine basis. For that the sensors are equipped with low weight operating systems called Contiki and TinyOS.The main objective here is the cloud of sensors and actuators are used as a service providers for data filtering for the efficient smart city management system [39].

Some of the recycling industries are using the robots to sort out the recyclable and recyclable waste. In this paper some modern tools, technologies, economical and hygienic artificial intelligence methods

for picking the garbage are discussed to address the waste management issues in many countries. In this work, the role of IoT is to separate the dry waste and wet waste with the aid of modern control system. In conveyor belt the dry waste is collected in the dust bin on one half portion of the bely and the wet waste is collected in the bins on the another side. Here IoT is used as a medium to control and monitor the waste for a single man and organization.By this effort they to develop all the rural and urban regions of the world [8].In this work the design for data sharing was made possible truck driver on time for the waste collection and the optimized route for garbage clearance by using the method called intelligent transportation system. This has been possible with the help of IoT components like RFID sensors, vision systems, controllers and surveillance systems to monitor the problematic areas in the waste collection and that supports the authorities [3]. This work includes design, implementation, and evaluation of IoT technology for the waste management in restaurants at Suzhou, China. The objectives are collecting, transportation and final disposal of the restaurant food waste. The developed IoT architecture with hardware and software to address the huge restaurant food waste yields fruitful results [60].

Here the waste management is automated with the help of IoT by gathering the garbage level through the webpage. For this; android application is merged with web server from the webpage the information will be sent to waste collecting vehicle and the officials. This smart garbage bin is considered to be the innovative method in waste management to make a clean environment. By this smart garbage system the overflow of wastes in public areas were avoided to prevent the common peoples from diseases[27]. Inefficient waste management will lead to environmental hazards and increase cost in waste management activities. Here smart garbage bin (SGB) has been implemented with IoT for the convenience of the users for information sharing of garbage through wireless network and it increases the battery life of SGB. This SGB have been used in the Gangnam district, Seoul, Republic of Korea, for the period 12 months. The report shows that waste of food were considerably reduced by 33%. They have developed the SGB in two modes 1. Standalone operation 2.cooperation based operation [21]. This work comprises of two studies one is related to the solid waste collection issues. The second study is about the IoT enabled kanban system is planned for waste management. The purpose of including the kanban is for the mean to sgnal time and quantity of waste collection.Due to this kannban system large volume of solid waste collection in the different geographical region is possible [57].

The overflow of garbage system will create unhygienic scenarios and it will affect the environment. To prevent this many concepts of effective smart garbage management system coupled with IoT is discussed but, each method has its own pros and cons.Here the smart garbage management system with, IoT, micro-controller, and Wi-Fi is used in many cities [24]. Three-layered architecture for IoT real time solid waste monitoring was designed in this work. The lower layer is equipped with input devices like sensors to sense the waste level in the bin. The second layer also called as middle layer includes wi-fi and GSM technologies is used for transmission of collected data from lower layer to the central system. Finally, the upper layer consist of cloud service for storing and receiving the data from the sensors. This device is designed with an objective to create a green environment. This system uses wireless sensor networks and different communication technologies to monitor the status of solid waste [11]. The routing issues in waste management issues is addressed by IoT enabled waste management. They implemented the smart cities with the distribution of waste trucks and waste bins are equipped with modern sensors and actuators with IoT enhancement to address the routing issues in waste management. Apart from the scheduling and routing issues this work focuses on stochastic reassign of trucks to collect the wastes generated [56]. This work discusses the necessity of new smart waste management system to improve the quality of life of the people. This is achieved by the use of internet of things (IoT) for smart recycling. This model includes dumpster with sensor, then this model is compared with present technologies for future scope of action [36]. Here the new type of technology called dynamic waste management model specially supported with IoT, sensors, actuators and radio frequency (RFID) for process monitoring and collecting of wastes in smart cities is developed. There are three phases in this model 1) waste collection planning and execution with the proper solution by restricting to the some locations. 2) Transportation of the waste depends on the type of waste 3) reusing the recycled waste. This work yields better results and provides excellence

in waste management. Analyzed the strengths and weakness of various models of IoT enabled waste management system [5].

2.2 Role of modern technologies

The automatic garbage collection system by introducing intelligence artificially to work as a garbage collecting robot. This robot act like an alternative compound to handle the waste management issues in the places especially in hospitals, theatres, supermarkets, grounds and many parks. The system function in which it uses the sensors to detect the garbage level, the volume of garbage generated and stored as database. This database is further sent to the servers. The data which is gathered is processed for cleaning the garbage collected. This method proves to be economical in comparison to the cost saved in transportation, human labors wages and finally it is a time saving process. The main components of the system function are microcontroller, sensors, battery output, and artificial intelligence. From the data collected the possibility of trash filling is calculated by statistical methods and based trash filling priority the trash will be cleaned for various locations in the country [45].Smart dust bin is the other concept it is assembled with piston arrangement which is used for the compression of garbage. This device is essential for the garbage overflow due to errors happening in the cleaning team [50].

The use of ICT (Information and Communication Technology) becomes necessary for the modern waste management it includes data acquisition technologies, spatial technologies, identification technologies, and data communication technologies. Which is necessary for planning, monitoring, collecting and managing the collected solid waste. This work reviews the fundamentals of ICT and their application in the solid waste management for planning and design of the new system[19]. Support vector machine (SVM), adaptive neuro-fuzzy inference system (ANFIS), artificial neural network (ANN) and k-nearest neighbors (kNN) are used for handling the waste. These four machine learning models provides better prediction of solid waste generation. These algorithms used to provide forecasting accuracy of waste generation in Queensland, Australia. Regression analysis, descriptive statistical models, time series analysis and deep learning models are the four different methods used to calculate the solid waste generation for the upcoming years. The result shows that machine learning algorithms shows good result in predicting the waste. Adaptive neuro-fuzzy inference system (ANFIS) were used to forecast the waste generation in the Logan city with the aid of time series. The results of ANFIS is compared with SVM (support vector machine) and KNN (K nearest-neighbor) models to find the best machine learning model to be introduce in future [37].

ANN (artificial neural network) have been used to calculate the solid waste generation in Mashhad city with the aid of time series dataset of waste generation. To compare the accuracy of forecasting regression results are compared with ANN. From this work the prediction for the solid waste generation for the year 2032 was made with ANN and it found to be the best results [40]. Most accurate model for the prediction of solid waste generation and diversion for more than 200 municipalities in province of Ontario, Canada .Two machine learning algorithms such as artificial neural network and decision tree models were used to predict the exact waste generation and diversion details based on the socio-economic and demographic criterias [25]. Used artificial neural network (ANN) to forecast the waste generation in Bangkok city. It doesn't yield better results because of large and noisy data.so it is needed to be processed with wavelet method. Developed the time series model and other suitable model for solid waste generation. ANN model is trained with back propagation algorithm [52]. Discrete wavelet transform and artificial neural network (ANN) is used for forecasting involving uncertainties in supply chain logistics. Discrete wavelet transform and (ANN) produce less bullwhip effect compared to Autoregressive Integrated Moving Average (ARIMA) model. Deep Neural Network models have been used to predict the data in various fields such as hydrology, supply chain demand forecasting, electricity price and load forecasting, flood forecasting. It is used in predicting waste generated by using time series dataset in Delhi from 1993-2011[21, 49]. This work presents the concept of smart management system for handling waste by using wireless sensor network and embedded system to collect the waste information. This device informs the authorities based on the information gathered to carry out this task wireless sensor network and embedded linux board . Linux board normally used here is Raspberry Pi [28].

Here the system is simulated from the waste data's collected in city of Copenhagen based on the geo-location data of the municipality location. Comparison is also carried out between the waste management using conventional method and intelligence method is carried out in city of Copenhagen [42]. Management of the waste efficiently and recycling it effectively will make the nation grow further. In this work various solid wastes like metal, glass, rubber, plastic and paper is separated effectively by the device electro-mechanical system using microcontroller and operational amplifier for sorting the solid wastes in an efficient manner. They work towards a motto to convert the conventional waste management approach to a smart system [38].Parallel mechanism is used to sort out the metals from the waste collected by using the sensors used in the mechanism. There are many mechanisms to sort out the required material from the waste. The efforts have been taken to convert the sort out materials into a useful product from the old recovered material [4].

Used littering quantification for the cleanliness and for the betterment of the city. To obtain this computer automated vision of the different types of wastes in the form of mages is collected in streets, sidewalks and other common places. Google net base vision application is used to classify the different types of urban waste this application accuracy varies from 63-77% in classifying different types of waste [46].Deeper neural networks are used mage classification but it is difficult to train this networks. Developed the learning framework easy for the training for neural network. The most recent development of deep learning lead to the improvement of computer vision. Deep Learning model has its application in picture segmentation, classification and detection. Developed the image framework ranging from 100 to 1000 based for easy classification of different objects [18].

Here the cloud-based waste management were carried out to monitor the waste management activities. Specific containers are allotted for each type of solid waste like plastic, rubber, metal, cotton etc and each container is connected with sensor. Information is updated to the cloud for effective sorting of the collected waste. This cloud-based waste management is not only effective in sorting and also it gives a desired route for the collection of waste. This method also paves the way for route optimization and to attain the efficiency in fuel and cost spent for the transport [1]. This work presents some demerits of handling waste management techniques in present situation and suggested the system is to be controlled by means of Arduino IDE. The system can read the depth of waste inside the container with the help of sensor and transmits the data to the central system through the wireless medium. Developed vision system for the huge waste collection in an economical manner with the aid of ultrasonic sensors. The role of the ultrasonic sensors is to collect the data from the dustbin and sent to the officials through Wi-Fi medium [43].A review on conventional waste collection technologies and the deficiencies in the current method is carried out. A unified heuristic algorithm is applied for the routing problem optimal and sensitivity analysis were conducted on the collection costs and for the environmental friendly approach. Proposed a smart and green waste collection for sustainable aste management in future [30].

2.3 Use of optimization techniques and algorithms

For the weighted graph shortest path and minimum spanning is computed in one origin. Considered Shortest path and minimum spanning were altered after computation. For the input computation of tree program they provide the number of analytic functions for lower bound. By this it provide solutions for all or for half of worst scenarios attained by other algorithms. This method is used to calculate the minimal distance between the two trash cans to optimize the trash collecting routes from various trash collection cans [47]. The minimum Linear Arrangement Problem and the Traveling Salesman Problem is similar combinatorial problem. In the minimum Linear Arrangement Problem simulated annealing and spectral sequencing are used for the approximations and they are found to be closer in their studies for lower and upper bound. Similarly another method called multi-level network is used when there is various sub-levels and multiple layers involved. This method yield better results only large scale network. But genetic algorithm (GA) is a better one to optimize the clearance paths of trash cans [29, 44, 53].This work uses the modified Backtracking Search Algorithm (BSA) in-built with capacitated vehicle routing problem (CVRP) models. This models are augmented with the smart bin concept to optimize the vehicle routing distance for waste disposal. By this method the huge amount of money spent for the waste management and air pollution is reduced due to the emissions from

vehicles [32].

Various decision-making algorithms are used in the solid waste collection these algorithm models are compared with each other. The comparisons are carried out for various performance metrics such as receiving data while the system in motion, multi objective, transmission loss of data, and increased data reception. Address the inefficient waste management challenges in smart cities by decision making model for IoT enabled objects with multiple goals. This method reduces data loss in the IoT data collection [33]. Shortest path model is proposed for solid waste management in Kanpur city. Here the program coding in C program is carried out the shortest path to find out optimal route for waste management. Developed C program is useful in identifying the shortest path between the two different locations for the waste collection. It also calculates the distance of the shortest path between the two different locations[15]. This work proposed is based upon artificial neural network (ANN) prediction algorithm to calculate the waste generation on the household size. Smart waste bin is designed to calculate the emptiness level of and weight of the bin so, it sends the direct information to responsible authorities [51].

Discussed the importance of prediction models in forecasting the rate of waste generation in Tehran city. Compared the various forecasting models such as Mean Absolute Percentage Error (MAPE), Mean Square Error (MSE), and ARIMA for the waste generation rate in Tehran. Final results shows that ARIMA is better prediction model compared to other models [34]. They developed the model with constraints such as bin maximum capacity and poisson ratio for waste arrival rate. When the garbage reaches the maximum value it sends alarm signal to the particular station it communicates the cloud for processing the data also finds the optimal route for waste collection [41]. This work focuses on the IoT elements and their characteristics. Elements comprise identification, sensing, communication, computation, semantics, and services. Characteristics involve communication identification and interaction. The review of smart waste management was conducted and the comparison of each methodologies were conducted[12].

2.4 Role of Radio Frequency Identification (RFID) in solid waste management

Radio Frequency Identification (RFID) is a modern technology which is used in various situations for tracing items and persons for the purpose of dynamic sharing of information like the older technologies like barcode. RFID smart tag is used for monitor and trace the cold storage in food applications[2].Radio Frequency Identification (RFID) and Sensor Network (SN) are used to minimize the impact of uncontrollable disposal of waste disposal. These technologies are used to track waste collection bin information of the concerned user without the support of information sharing system. The smart bin used with RFID tag is also for sorting the waste of different types for further recycling operations[14]. These (RFID) are used to measure the weight of the garbage bin in the each and individual household garbage collection. Developed the RFID system with load sensor cell to automate the waste management process to reduce the waste management cost. This design is also useful to streamline the waste such as recyclable and non-recyclable waste[10].VGG-16 pre-trained CNN is trained to identify nearly 1.2 million objects from imagenet data set.so this RFID's are used to identify 1000 different objects. Both VGG-16 and alexnet are used for photo classification both these forms shows minimum error when trained for million objects. This technologies are used to avoid the segregation confusions in recycling process [48].

Alexnet is a platform among the convolution neural network which has a repeated convolution layers followed by max-pooling with the best results obtained from the dataset used for waste classification with its stored 1.2 million images of multiple layers. They also verified that if any one of the layer is removed it results in the lagging performance by 2% [26].The integrated approach of architecture called Convolution network is used for classification and detection. Novel deep learning approach is combined with ConvNet for better classification and detection. Convolution neural network (CNN) is used in analyzing the visual image here it takes things which are going to be investigated as input and classify them into different materials. Large convolution networks is developed for image classification and it proves to show superior performance in classification with different model layers [54, 59]. It has many hidden dense layers such as polling layers, fully connected layers convolutional layers and normalization layers. RFID in combination with communication technologies were used in solid waste

bin and truck monitoring system. Algorithms were developed for the real-time implementation. By this arrangement, information stored is used for waste management processing activities. This method yields better results for solid waste management [17]. Waste tracing is done by RFID in collection services of waste management. Some simulation analysis has been conducted to check the impact of introducing the new technology in the waste management procedures. Finally, the application of RFID in various organization collection methods are compared in terms of economic and technical criteria [35].

Discussed the role of RFID in integrated approach of solid waste management for improving the waste and resource management in Switzerland. Here the waste chain analysis starting from waste production, waste separation and waste treatment were carried out. By the application of RFID the recycling growth rate improved in a consistent manner[7]. RFID's are used to trace bin distribution in waste management system, before the usage of RFID this tracing work was done by labor force which is higher compared to the usage of RFID[13].Real time monitoring of information regarding the storing and transportation of solid waste have been maintained accurately by the RFID,GPRS and GIS for pollution control and environmental protection. By this well monitoring system the hazardous waste generation were reduced much compared to the traditional approach [31].Some issues in the hazardous waste producers in Brazil in close monitoring of transporting these hazardous waste and disposing it at right destination. Because it poses serious threat and vulnerable situation to the environment. This issue was addressed properly the new system design and prototype of RFID by closely monitoring the transportation of hazardous waste in Brazil and disposing it in the desired location[5]. The issue of improper solid waste management in Kanpur city, India related to improper information regarding transportation and disposal of disposal for the generated waste. Taken into account this problem were solved by the application of communication tools like RFID, GSM uses and other related software packages [55].Metropolis like in Shanghai, China there is a problem in maintaining efficient waste management including collection, transportation and disposal. This issue were solved by 3R's concept of reducing, reusing and recycling the generated solid wastes have been properly sorted out with help of information technology through RFID.This technology proves to be the cost effective waste management system [58].Huge amount of waste sorting is a difficult task and also doing it in a manual manner is unhygienic especially during the pandemic situation like COVID-19. Deep learning integrated with convolution neural network (CNN) is trained with large data sets used for testing the accuracy. This is carried out in sorting the different waste like sheet metal, card board, and glass and metal tins[9].

3 Key findings and suggestions

In most of the developing countries they are following only conventional mode of solid waste management. The introduction of the intelligent system as discussed earlier in this work will minimize the cost incurred in the solid waste management.

The wireless mode of network by the IoT sensors, RFID tags, Transducers will solve the waste corporation officials by clearing the garbage bins in a timely manner.

The intelligent methods discussed in this paper will improve the recycling opportunities in most of the countries. Because these methods are very useful in sorting the recyclable and non-recyclable waste.

It is safer to handle the hazardous waste by the modern technologies than the conventional approach.

Their accuracy of the well trained convolution neural network by more than a billion of classified mages is very useful in sorting the different types of wastes for efficient recycling operations.

Also this mode of smart waste management will reduce the chance of virus infection especially during the pandemic period COVID-19.

4 Conclusion

The role of artificial intelligence, cloud computing, Internet of things, optimization techniques, algorithms and modern technologies is very essential for the solid waste management (SWM).In the conventional mode of waste management it discusses about the transportation, collection and disposal is of manual method it makes all the developing countries to spend much higher for the waste management. Even the treatment of this solid wastes involving sorting activity to sort out the recyclable and non- recyclable wastes .to carry out this all municipal corporations have set a huge amount for the labors working for the recycling activities.As mentioned earlier it is unhygienic and cause some infectious diseases especially during the pandemic period covid-19 the whole world is facing. Now it's time for all developing countries to think of all the modern technologies as discussed in this paper to harvest the benefits from it to maintain the efficient SWM.

Competing Interest

Authors declared that there is no competing interest exists.

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