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Smart Solid Waste Management System

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Abstract – *Solid Waste Management has become one of the major concerns that the world is facing at present. In the present scenario, to detect, monitor and manage the waste in the dustbins especially in large residential areas is highly impossible and it requires more human labour and cost.*

These problems can be overcome by introducing a Smart Solid Waste Management System which involves the use of pneumatic pipelines for transporting different types of waste materials from each flat, as in the case of apartments. The waste can be segregated on the basis of the colour of the waste bags in which it is disposed. This is made possible using a waste segregating setup that is controlled by an electrical circuit. The wastes are collected at a central station. The food waste and plastic waste are treated in a biogas plant and plastic pyrolysis plant respectively. The end products can finally be collected and utilized for various purposes.

This proposed system keeps an eye on the solid waste and manages the overall collection process, thus reduces human labour to a large extent and is a sustainable method of waste disposal. The increased implementation of technologies such as Pneumatic Waste Collection Systems (PWCS) will improve and enhance upon conventional methods of waste collection and minimize some of the issues associated with existing collection methods, such as access, timing, frequency of collection and excessive number of vehicle movements.

***Key Words*: Smart solid waste management, solid waste, pneumatic waste transportation, Kochi waste issues**

1. INTRODUCTION

The time waste was considered as a leftover that had to be disposed of somehow is long gone. With the realization that our resources are not inexhaustible came the awareness that our waste offers economic opportunities that have to be taken advantage of. While some products containing glass, metal, etc. can undergo recycling, it is important to point out that the non-recyclable waste materials can be used to produce energy.

While emphasizing the durability of waste, we have to think about running the waste cycle efficiently too. Waste management is more than just collecting waste. It is the collection, transport, processing, recycling, disposal and monitoring of waste materials. Numerous factors, such as environmental, eco-nomic, technical, legislation, institutional and political issues, have to be taken into consideration.

In the past, solid waste collection was carried out without analysing demand and the construction of the routes was left over to the drivers. Cities, however, continue to expand. Because of this ongoing urbanization, the importance of an efficient collection system only increases. Unfortunately, this problem cannot be solved simply by eliminating its ultimate cause, garbage, since these materials are as inevitable a by-product of human civilization as are the other kinds of solid and liquid wastes that people produce. Unscientific waste handling is also one of the major causes of on the ongoing climate change which needs to be tackled as early as possible.

This paper discusses some of the problems found in the solid Wate management in the metropolitan city of Cochin and suggests possible approaches for improving the situation. Although the environmental consequences are often quite evident, the problem is seldom dealt with. Reasons for not dealing with the problem are low political priority, inadequate resources allocated, and/or missing know-how regarding alternative solutions for operating and managing a landfill/dump.

2. LITERATURE REVIEW

G. Kalyan Chakravarthi, D. Satish Chandra and SS. Asadi (2019) [1] studied the expanded epidemic outbreaks and spreading of infections in the New Capital City of Amarvathi due to inappropriate waste administration in urban areas which are having a drastic and exponential population growth. In current circumstances, the Garbage Collecting Vehicle (GCV) amasses the waste few times in a week. In this way, the issue is over streaming of waste on the streets.

The data obtained based on the studies conducted in Tullur, Rayapudi, Velagapudi, Nelapadu villages showed that pneumatic system is best suitable for the increasing population when compared to RFID (Radio Frequency Identification Devices), M2M (Machine to Machine) and IOT (Internet of Things).

M. Balasubramanian (2015) [2] observed that the recycling industry in India needs to be improved through increased professionalisation, market development and clear operating standards. The recyclables could be straightway transported to recycling units which in turn would pay certain amount to the corporation thereby, adding to their income. He also suggested that proper segregation would lead to better options and opportunities for scientific disposal of waste It is projected that by the year 2031 the MSW generation shall increase to 165 million tons and to 436 million tons by 2050 (MoEF&CC, 2015) [3].

He also pointed out from a CPCB report that out of 1.18 lakh metric tonnes waste generation (82%) is being collected and the remaining 18% is littered. Moreover, out of the total collected waste, only 0.33 lakh metric tonnes (28% is being treated and disposed.

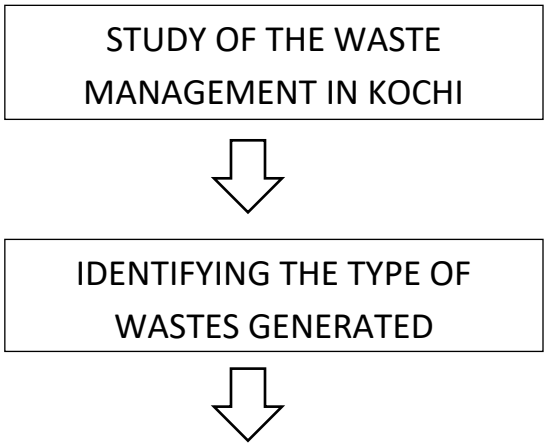
Giovanna Mangialardi, Gianluca Trullo, Francesco Valerio and Angelo Corallo (2016) [4] concluded from their findings that a pneumatic refuse system can enable substantial money saving and at the same time a remarkable CO2 saving process.

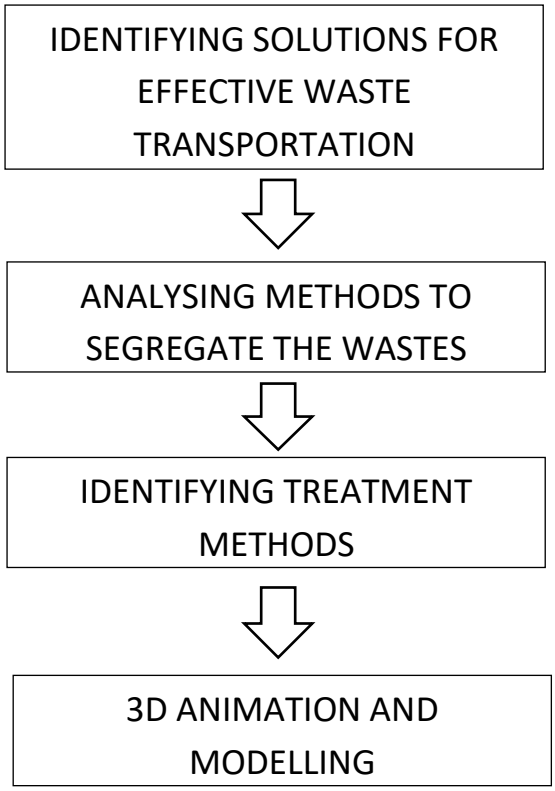
Both these effects are enabled for mainly two strictly consequential reasons. The first one is that using a buried pipe system to convoy the waste will remove from urban streets most if the vehicle deputy to the collection and this brings either a reduction of costs and a reduction of their polluting emissions.

Waste collection is one of the life cycle phases that influence the environmental sustainability of waste management. At present we follow with door-to-door collection, recycling and land -filling disposal. This system is highly flexible; however, it has several drawbacks giving rise to important environment impacts and difficulty (Chirag Paliwal, Vishnu Agrawal, Saurabh Tege, 2017) [5]. One of its weak spots is found in collection process of waste streams following a conventional door-to-door collection using a combination of trucks and waste bins. Hygiene issues, efficiency shortfalls in waste collection, traffic disturbances and environment burdens in urban areas relating to the increased noise and air-emissions are some of its major disadvantages.

3. METHODOLOGY

The various steps involved in our work are represented below in the form of a flow chart:





4. SOLID WASTE MANAGEMENT IN COCHIN

Cochin, called the 'Queen of Arabian Sea', is one of the biggest cities in Kerala situated in the district of Ernakulam. As of 2011, it has a total urban population of more than of 2.1 million within an area of 440 km^2, making it the largest and the most populous metropolitan area in Kerala [6].

Together with the growth of the metropolitan city and its continuous and rapid expansion, there has also been a significant increase in the amount of waste generated per day. The waste management here is still an unresolved issue and the authorities have still not found a proper way to deal with it. Even though the residents are being encouraged to treat the waste at home itself, this is not possible in many of the urban areas especially in the apartments due to lack of space availability.

The people residing in apartments segregate the waste at home into biodegradable and non-biodegradable bins which is collected by the municipality or kudumbasree workers. About 60% of the total waste collected is segregated at the source itself. Since several municipalities in Cochin do not have their own treatment facilities for even the biodegradable waste, the only option is to transport all of the wastes to the centralized solid waste treatment plant at brahmapuram.

Brahmapuram is an area located around 20 kilometers from Kochi city. It is a small Village in Vadavucode Block in Ernakulam District which comes under Kunnathunadu panchayath. Spread over an area of 110 acres, it has been identified as the hub for waste management activities. Since 2012, municipal solid waste of 5 municipalities (Aluva, Angamaly, Kalamassery, Thrikkakara, and Tripunithura) and 2 panchayats (Cheranalloor and Vadavucode-Puthencruz) and the solid waste of Kochi corporation are handled by the Kochi Corporation and taken to Brahmapuram plant [7]. Of the 305 TPD of solid waste generated in the city, 230 TPD of MSW is collected, and of which 130TPD is processed while 100 TPD is disposed-off at the landfill site [8].

4.1 EXISTING TREATMENT FACILITIES AT BRAHMAPURAM

The Brahmapuram solid waste treatment plant is treating only biodegradable waste at present [9] using aerobic windrow composting and all the other wastes are openly dumped in an unscientific manner. There also exists a Refuse Derived Fuel (RFD) facility, vermicomposting plant, plastic shredding and bailing unit, all which are non-functioning at present [10].

The windrow composting unit is basically a roofed structure with paved floors having open sides. The State Pollution Control Board (SPCB) officials who visited the plant in February last year noticed that the structure is in a dilapidated condition and reconstruction will incur huge amounts of money. It does not have a windrow formation plan and the windrow size is not being followed. The trommel screens are not working and the shortage of trommel units has resulted in the reduced production of compost compared to the quantity of waste brought to the yard. They also observed that it was impossible to follow a scientific windrow pattern as the entire site premise has been over filled with legacy waste [11]. Thus, the biodegradable waste that cannot be treated is being dumped along with the other wastes. Moreover, the manure produced do not meet the fertilizer standards as per the SWM rules, 2016.

4.2 ISSUES ASSOCIATED WITH THE CURRENT UNSCIENTIFIC PRACTICES-

The current solid waste management practices cannot be considered sustainable and is adversely impacting the environment. The plant has found to be violating the Solid Waste Management Rules, 2016 and has been operating without an authorization for the last 11 years.

Fig: 3.1 Waste heaps at Brahmapuram Solid Waste Treatment Plant

(Source: the news minute: NGT slams Kerala govt. for lack of 'meaningful action' to manage solid waste, January 2020)

The leachate from the plant is found to be a major source of pollution of the Kadambrayar river, which is identified by the Central Pollution Control Board (CPCB) as one of the most polluted river stretches in India. This has become a major issue as the river serves as the source of water supply to the nearby panchayats including the IT firms at Kakkanad and Smart City. The situation is likely to aggravate with the onset of monsoon. Tests of samples collected by the State Pollution Control Board from the leachate drain at the solid waste management plant have revealed exceeding levels of biological oxygen demand and other parameters. Thus, the disposal of untreated leachate impacts public health as well as the pollution of the natural water body.

Survey reports among the people residing within 5 Km from the brahmapuram plant shows that the odour from the plant is extremely unpleasant and this was also one of the main reasons why people fled from the nearby places at the time the dumping began in 2007.

Transportation of the waste manually in open trucks and tempos is also causing severe odour nuisance in the locality. The available number of trucks are not sufficient for the current waste collection [12]. Moreover, transporting the waste is also costly. During the financial year 2020-2021, the contractors have been paid a sum of ₹6.39 crores by the corporation for transporting wastes to the yard.

The plant has turned out to be a dumping yard to be more specific with lack of scientific management of waste and inadequate maintenance of the treatment facilities. The National Green Tribunal (NGT) and State Pollution Control Board had warned the Cochin cooperation to take initiative to handle the situation but no such efforts have still been taken which is making the current scenario even worser day by day.

Even though the authorities are strictly monitoring the proper disposal of the waste, sights of wastes dumped on streets are not uncommon in Cochin. In Kalamassery, Thrikakara and Eloor municipalities, this practice has been increasingly common in recent times [13].

Fig 3.2 Waste dumped along the roadside in Kalamassery

(Source: G. Krishnakumar, April 2021, Municipalities in Ernakulam fail to ensure proper Waste Management Survey, The Hindu)

Surveys point out that the centralized waste management facilities at several municipalities have become mere dumping sites with no scientific treatment of the wastes.

Moreover, the door-to-door collection of waste amidst the present covid-19 pandemic has become a serious concern. With lockdowns, halt on public transport facilities and travel restrictions imposed, the workers who collect wastes from houses are forced to do their job somehow, instilled with the fear of contracting the virus since it is an essential service. This may pose serious threats to the life of the workers and further the spread of the virus. There were also reports of waste collection affected in several divisions of the Cochin cooperation during the crisis.

All these show that there is an immediate need to take initiatives that can tackle the problems at hand without aggravating the situation. Scientific means of treating the waste should be incorporated into the current solid waste management system.

5. PROPOSAL FOR A SMART SOLID WASTE MANAGEMENT SYSTEM

Smart Solid Waste Management System is an efficient means of handling wastes from the point of generation of the waste itself. It involves the use of powerful vacuum pumps and underground pipes for waste transportation to a central collecting point where it is either treated or further taken for recycling.

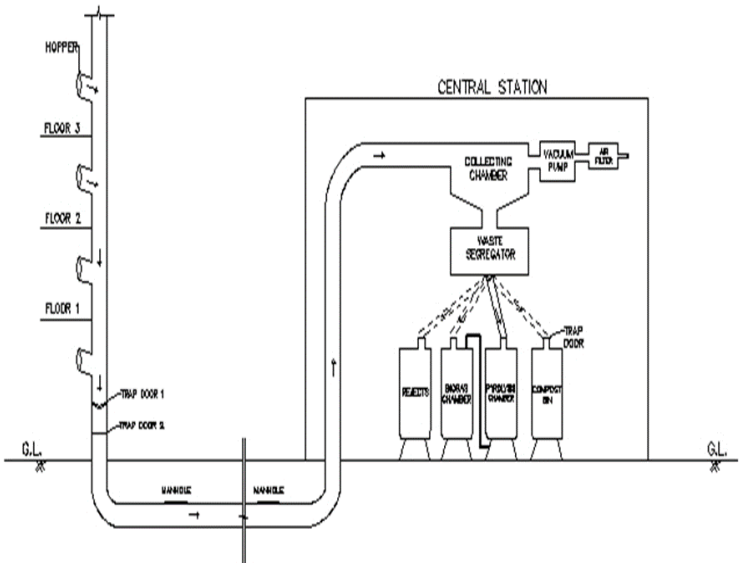


Fig 4.1 Layout Diagram of Smart Solid Waste Management System

5.1 WORKING MECHANISM OF THE SYSTEM

The waste is initially disposed through the inlet point which is a self-closing door attached to the vertical pipeline and installed in each of the flats or floors of an apartment. The refuse falls down under the force of gravity through the pipe bypassing two trap doors, say trap door 1 and trap door 2, and is collected at the bottom.

The trap doors are installed to ensure that the pipeline is completely sealed when the vacuum starts operating even when the inlet door is opened by the residents to dispose of the waste. The purpose of providing the trap door 1 is to prevent the waste bags from getting jammed in the trap door 2 and obstruct its closing. So, the time of closing of the two trap doors need to be controlled in such a way that the trap door 1 first closes and holds any waste from moving further down after a second or so the second trap door shuts. Also, there are chances of the waste piling up below the trap door 2 and block it from closing. This is signaled by a level sensor to turn on the vacuum.

When both the trap doors are closed, the vacuum turns on. After a certain amount of time, the vacuum comes to a halt and the trap doors open again. The time required depends on the capacity of the vacuum pump which in turn depends on several factors such as the maximum weight of waste bags, distance it is to be transported, the velocity at which is carried and the friction in pipes. This cycle repeats itself and is controlled by an electrical circuit. The air exhausted by the vacuum is passed through a filtering system to remove any odour from polluting the environment.

The vacuum sucks in the waste through the pipeline and transports it to the central station. It is dropped into the collecting chamber which is followed by the waste segregation process. Depending on the colour of the waste bags, it is separated into different chambers, the compost bin,

biogas chamber, plastic pyrolysis chamber and the rejects bin, all of which are installed with self-closing doors. The end products can be removed at regular intervals. The detailed working involved in waste segregation and the different chambers is explained in the chapters that follow.

6. SEGREGATION OF WASTE

Segregation is an essential step required to carry out an effective waste management system. All kinds of waste cannot be treated in the same way. Each type of waste requires a different treatment method. Segregation, thus, makes the treatment part easier by separating the waste from the source of its generation itself. Effective segregation of wastes means that less waste goes to landfill which makes it cheaper and better for people and the environment. It increases the recycling rates and is also important for public health.

Manual segregation of bulk waste by the municipal workers is time consuming and unhygienic. Thus, it is important for the residence to separate the waste at home itself. This is made possible in our system by segregating the waste on the basis of colour at home and then providing a waste segregating setup controlled by an electrical circuit. The wastes are to be disposed of in separate, coloured bags depending on the type of waste.

The various colours used to identify the waste are as follows:

- green bags:

They are used for biodegradable waste and includes food waste and paper waste. They are made of organic materials since they will be directly reaching the biogas plant to be decomposed.

- Red bags:

They are used for plastic waste. These bags could be made of plastic itself and are sensed by the waste segregator and disposed into the plastic pyrolysis chamber.

- Blue bags:

There are certain items that cannot be put into the biogas plant as it does not undergo sufficient degradation which has been discussed in the coming sections. Thus, the blue bags are utilized for such items to carry it to the compost bin and obtain manure.

- Yellow bags:

All the other rejects which include metals, electronic waste, etc. can be collected in the yellow bags.

The waste segregating setup used in our waste management system is controlled by an Arduino nano, a color sensor, two servo motors, switch and connecting wires.

7. BIOGAS PLANT

Food waste is the common type of waste generated at all households. Proper collection and its disposal are of utmost importance because these are mainly organic, biodegradable matter which starts decomposing in a short period of time. Thus, the unscientific disposal of food waste can lead to air pollution, odour nuisance and affect public health. The waste reaching the brahmapuram plant also contains mixed waste which is dumped at the site. The decaying organic matter produces methane, carbon dioxide and other gases which is not properly collected. This is thus, a major environmental issue.

A solution to this concern is to setup a biogas digester. A biogas plant is where biogas is produced by fermenting biomass. The substrate used for the production of this methane-containing gas usually consists of energy waste materials such as manure or food waste. The fermentation residue left over from the substrates at the end of the process can be used as fertilizer.

In this smart solid waste management system, the biogas produced is utilized to fuel the plastic pyrolysis chamber. Excess amounts if obtained can be provided to the residents to replace LPG (Liquified Petroleum Gas) which is a key source of primary cooking fuel in urban India.

7.1 EXPERIMENT

AIM:

To determine the duration for which the biogas obtained from food waste in a biogas digester could burn.

MATERIALS:

a 120L drum, a tyre tube, gas hose, two control valves, a tap, m seal, a 60cm long pipe

PROCEDURE:

- After setting up the biogas plant as shown in the figure below, it is filled with 30 days old cow dung to about three-fourths the chamber.
- About 4kg food waste is added to it.
- Leave it undisturbed after ensuring that all the valves are in proper position and there isn't any cracks or holes in the biogas chamber. The 60 cm long slurry outlet pipe should also be tightly closed.
- Observe the formation of gas in the tyre tube.

Fig 6.1 Biogas Plant Setup

OBSERVATION:

- It has been observed that the gas started forming in 10 days and filled the tube in 15 days' time.
- The gas when lit burned for about 15 minutes.

8. PLASTIC PYROLYSIS PLANT

There has been no revolutionary material than plastics. Almost everything that we use is made of some form of plastic and has become an integral part of our daily lives. This material offers numerous properties such as lightweight, resilience, resistance to corrosion, color, transparency, and ease of processing, which makes them superior over other materials in many applications.

The various types of plastics commonly used are categorized as Polyethylene Terephthalate (PETE), High-Density Polyethylene (HDPE), Polyvinyl Chloride (PVC), Low-Density Polyethylene (LDPE), Polypropylene (PP), Polystyrene (PS) and Others that includes acrylic and nylon types of plastic.

Pyrolysis of plastic is a chemical recycling method of waste plastic into useful products at high temperatures in an oxygen free environment. This process is carried out at high temperatures. The critical temperature ranges for obtaining pyrolysis products are between 350 and 500°C. The process can use self-produced pyrolytic oil or gas to reach such high temperatures. In this respect, the process can be performed by consuming less energy from the outside.

Moreover, our system is designed in such a way that that the biogas obtained from the biogas plant is used to fuel the pyrolysis chamber.

The plastic waste disposed in the red colour bag which is segregated by the waste segregation machine enters the plastic pyrolysis chamber. Heating of the chamber raises the temperature of plastic and gets converted into the gaseous form. The gas entering the condenser liquifies to produce mixed oil. The non- condensable gas is either used as fuel in heating the pyrolysis chamber or used to dry the plastic in the drier. The mixed oil can be refined using a fractional distillation column to obtain useful liquid oil.

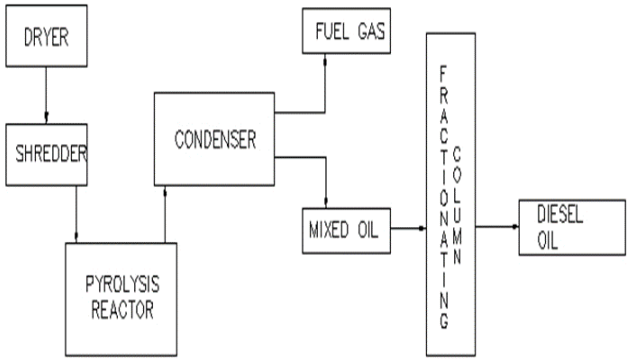


Fig 7.1 Schematic Diagram of a Pyrolysis Plant

The products formed at the end of pyrolysis include solid coal (char), liquid pyrolysis oil, and gas. The proportion of each end product depends on the type of plastic, temperature, time, heating rate, and pressure, residence time, reactor design and configuration.

The liquid product obtained from pyrolysis can be converted into a fuel of very similar properties to diesel or gasoline fuel after secondary processes.

The gaseous product of plastic pyrolysis contains mostly carbon dioxide, carbon monoxide, hydrogen, ethane, methane, ethylene, etc. The pyrolysis gas product may provide heat for the pyrolysis reactor or used to dry the plastic waste or may be used for the generation of heat and electricity in a gas turbine system. This, thus, improves the efficiency of the pyrolysis process and does not let any byproduct be released into the environment.

The solid product that has a high surface area and large pores that is released as a result of the pyrolysis process can be used as activated carbon.

This method will help lessen the burden on the existing fossil fuel reserves which is expected to deplete in the near future. However, sophisticated equipment, pollution control mechanisms and careful designing of the various components are required for setting up a plastic pyrolysis plant.

8.1 EXPERIMENT

AIM-

To determine the quantity of liquid by product obtained from the pyrolysis of various types of plastics.

MATERIALS-

a metal can, two containers, ice and an open thermocol box

PROCEDURE-

- The various parts are first assembled and is shown in the figure below.
- The experiment is conducted using LDPE type of plastic.
- The steel drum is first filled with the plastic.
- After ensuring that the entire system is completely sealed, it is heated to a temperature of about 300-700^{0}C under normal atmospheric pressure.
- Note the time at which the ignition was initiated.
- Observe the formation of gas in the pipe and its subsequent condensation in the condenser.
- The process is continued until no further condensation is found to take place.
- Measure the amount of mixed oil obtained and the time taken for its formation.

Fig 7.2 Plastic Pyrolysis Setup

OBSERVATION-

QTY OF MIXED OIL FROM LDPE: 11 ml

TIME TAKEN: 45 minutes

9. COMPOST BIN AND REJECTS

9.1 COMPOST BIN

A compost bin is a chamber in which the organic waste is converted into compost over time. It is a method for treating the solid waste in which the organic material is broken down by microorganisms to a point where it can be safely stored, handled and applied to the environment. The finished product is called 'humus' or 'compost'. The bin is to be designed as a continuous chamber where waste is added through the top and compost is collected from the bottom.

Microbial action is achieved either through an aerobic or anaerobic decomposition process. Anerobic decomposition, which takes place in the absence of oxygen, is chosen here over aerobic decomposition as the maintenance required is comparatively less and unpleasant odours are eliminated in a closed chamber. Liquid manure and solid compost are obtained once the waste is decomposed.

The compost bin is incorporated into this system as all the biodegradable matter is not taken up by the biogas chamber and such materials may reduce its efficient working. These items include onion peel, egg shell, coconut shell, huge quantities of citrus fruits, woody materials and cardboard. These items are initially put in a yellow bag made of biodegradable material and disposed of which eventually reaches the compost bin.

9.2 REJECTS

All the other waste materials that cannot be handled by the compost bin, biogas and plastic pyrolysis chamber is disposed into blue bags and ends up in the rejects chamber. This could include metals, glass, e-waste and biomedical wastes. They are collected, segregated and can be sent off for further recycling at the appropriate recycling centers.

10. LIMITATIONS

- The initial costs of setting up a smart solid waste management system can be high.
- It requires that the right type of waste be disposed into the right coloured bags. This should be carefully done by the residents who are to be given proper awareness on how this waste management system works. Any mistake from the part of the residents can lead to its inefficient working. Thus, the willingness and cooperation of the residents is of utmost importance.
- Studies show that unlike the other plastics, PVC plastics in a pyrolysis chamber can produce toxic substances which can affect the pyrolysis products formed. But they have a potential to be recycled. Thus, these plastics may be required to be collected along with the rejects and sent to the recycling centers.

11. CONCLUSIONS

- The development of new approaches for the management of urban waste has become a big issue for modern society as traditional methods of waste management have proven to be unsuccessful over the past several years.
- It is high time that we shift to a sustainable and environment friendly method of waste disposal that is hygienic and thus, safeguards public health. Smart Solid Waste Management System is one such approach which can be established in places with space limitations and helps the

residents as well as the municipal authorities to handle the waste generated efficiently.

- A city like Cochin can benefit a lot from such a system in many aspects. It will help in handling mainly the food waste and plastic waste from the point of generation to the point of its treatment and the remaining wastes can be collected and send for further recycling.
- A treatment plant like the Brahmapuram Solid Waste Treatment Plant which is currently a mere dumping site can be replaced with this system thus protecting the surrounding rivers and the environment. The legacy wastes dumped at the site can also be treated to some extend in this system.
- It will completely eliminate the transportation expenditure incurred in transporting daily waste to the site.
- The number of workers required by this system is significantly less when compared to the traditional waste management system.
- The odour nuisance is also prevented as the entire system is completed closed.
- All these will bring great relief to the authorities who have been struggling with waste management issues in Cochin over the last decade.
- More feasibility studies and then its designing is to be carried out in order to decide on whether they can act as centralized or decentralized units.

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