DEPARTMENT OF ELECTRICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY ROPAR

Horticulture Waste Management and Processing- Under the guidance of Dr Suman Kumar

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Candidates' Declaration

We hereby certify that the work which is being presented in the project entitled "Horticulture Waste Management and Processing " is submitted in partial fulfilment of the requirements for the award of the degree of Bachelors of Technology to the Department of Electrical Engineering, Indian Institute of Technology Ropar, India, is an authentic record of our work carried out during the period from Jan 2022 to May 2022 under the supervision of Dr Suman Kumar.

We declare that this written submission represents ideas in our words and where others' ideas or words have been included. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed. The matter presented in this project has not been submitted by any of us for the award of any other degree at this or any other University/Institute.

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Finally, we must express our very profound gratitude to our parents and to our friends for providing us with unfailing support and continuous encouragement throughout our years of study and through the process of researching and writing this project. This accomplishment would not have been possible without them.

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Abstract

While India focuses on the Swachh Bharat Mission, there are still many hurdles in waste management. These hurdles are even more potent when it comes to horticultural waste. Many cities with responsible local governments are unable to decide between various methods of horticulture management and as a result these cities often end up using counterproductive or inefficient methods. One such example is the overuse of landfills in horticulture waste management, these landfills not only make the land unfit for construction but also create air pollution through odour. It is because of the myth that advanced technologies of waste management are costly and difficult to implement.

This report tries to break this myth by providing various effective, affordable and easy methods of horticulture waste management. To study these methods various reports on best waste management in Indian cities, future technologies and waste management startups are looked at. This report also looks into case studies to analyze the feasibility of a method. In the end, this method also tells in detail that if a city or individuals want to use a method for horticulture, waste management companies or resources can offer them these services.

1. Introduction

India is home to 1.2 billion people, with a decadal population growth of about 18%. Hence generation of humongous amounts of waste is expected. This waste can be divided into 2 major categories: -

1. Biodegradable
2. Non-biodegradable

Biodegradable waste includes a wide range of waste, from cloths to paper to horticulture waste. In this report, we consider the management of horticulture waste.

Horticultural waste refers to tree trunks and branches, plant parts and trimmings generated during the maintenance and pruning of trees. Although wide definitions of Horticulture waste include agricultural waste, for the purpose of this report we would not consider agricultural waste to be part of horticulture waste.

The amount of horticulture waste in the cities varies from 20% to 50%.

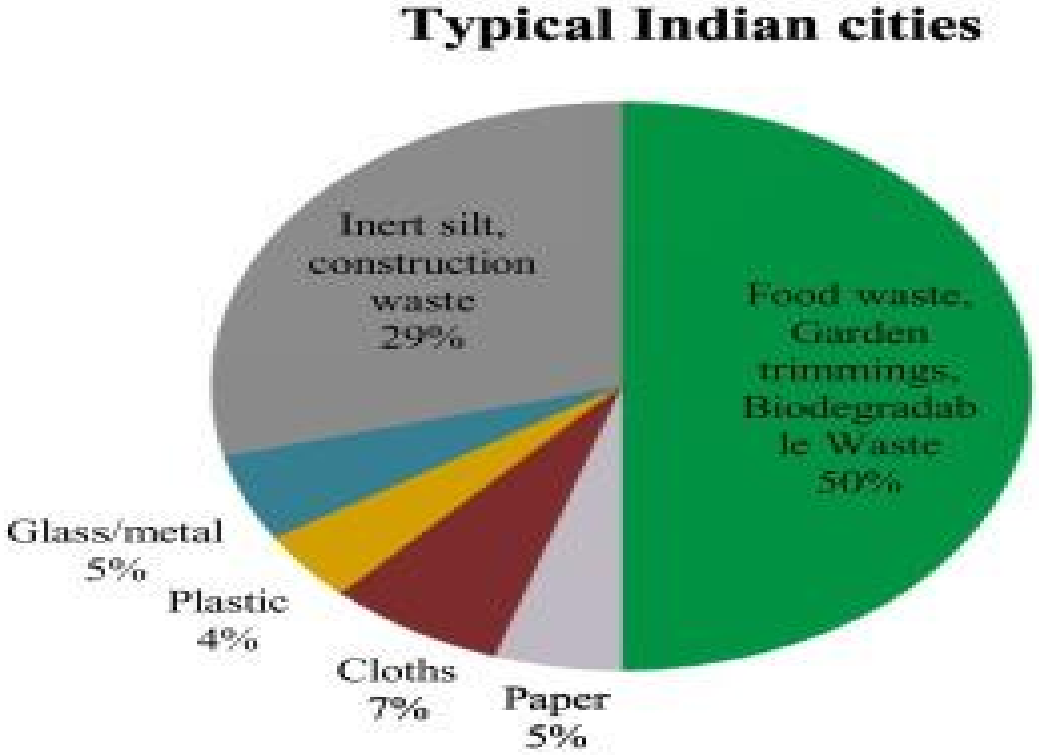

Fig. 1: Share of various types of wastes in Indian cities.

If this waste is not efficiently managed it often leads to problems of air pollution because of odor, it also can create a medical hazard as many mosquitoes and bacteria find this waste habitable.

a. Motivation

Even in current times when we have various efficient methods of waste management, only few cities and towns have adopted them. We wanted to find optimal methods of waste disposal and use our electrical engineering knowledge to provide with a detailed plan to adopt these methods for cities and towns. This waste management is crucial for Swachh Bharat Mission and to keep our localities clean and hygienic. With proper knowledge of electrical engineering and research we were able to find many methods which can be a game changer in horticulture waste management.

b. Existing Work

Although there are many methods and techniques used for horticulture waste management, we will discuss prominent ones.

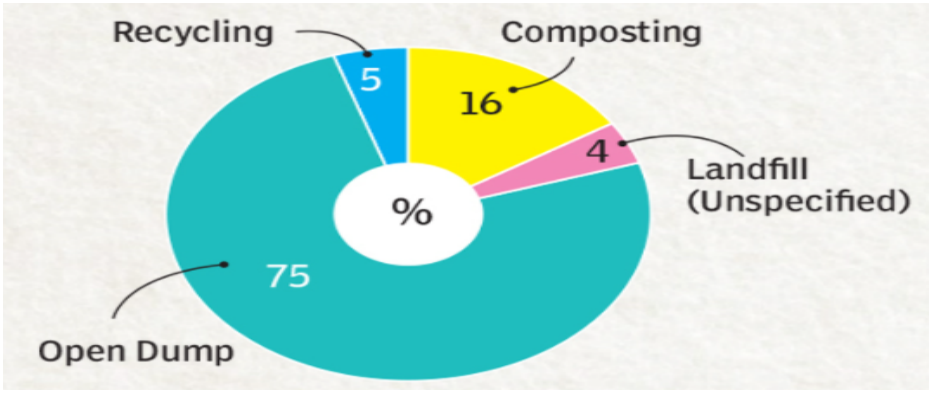

Fig 2 Types waste disposal methods

1. Open dump

Sadly, in India the most common form of waste disposal is dumping, in fact according to certain statistics 70% of waste disposal in India is in the forms of dumping. Various hazards are associated with the waste dump sites, e.g. surface water contamination, groundwater contamination, bad smell or odor, release of greenhouse gasses, accidental hazard caused by fire, slope instability, loss of vegetation, Soil contamination and bird-hit etc.

2. Landfills

Throwing daily waste/garbage within the landfills is the most popularly used technique of waste disposal used nowadays. This method of waste disposal focuses attention on burial the waste within the land. Landfills area units are usually found in developing countries like India.

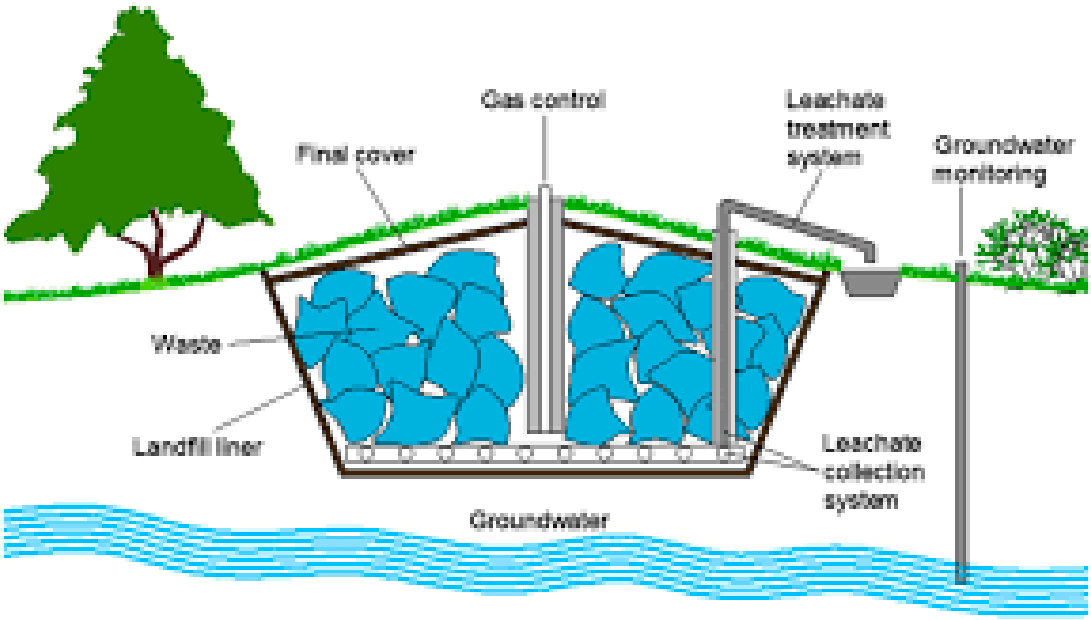

Fig 3 Landfill structure

But there are various concerns related to these landfills

a. One tonne of horticulture waste in landfill can produce about 400-500 cubic meters of landfill gas. Landfill gas contains methane and carbon dioxide as the major constituents and traces of other gases. Methane is a greenhouse gas that is 25x more potent than carbon dioxide. Hence **landfills can be a cause of global warming and climate changes.**
b. Since methane is highly inflammable, without proper ventilation these landfills can be a cause of explosion. These explosions are prominent when methane concentration is 5-15% of the total air volume.
c. Many landfills in India lack proper protective membrane, hence hazardous chemicals, gases, and toxins seep from landfills and cause soil and groundwater contamination.
d. These sites become prone to collapse and can cause disasters. A massive landfill outside Ethiopia's capital, Addis Ababa collapsed in March 2017 and 113 people had died.
e. In India Landfills are near slums and residences of poor people. People living near or prolonged exposure to landfills have been linked to cancer, respiratory disorders and developmental defects in children.

3. Incineration/Combustion

Incineration or combustion could be a kind of disposal technique within which municipal waste units are burned at high temperatures so as to convert them into residue and gaseous products.

Although a proper incineration plant can prevent hazardous gas, they are very expensive. Hence in most parts of the country these incineration plants are not used and rather only ineffective combustion methods are used.

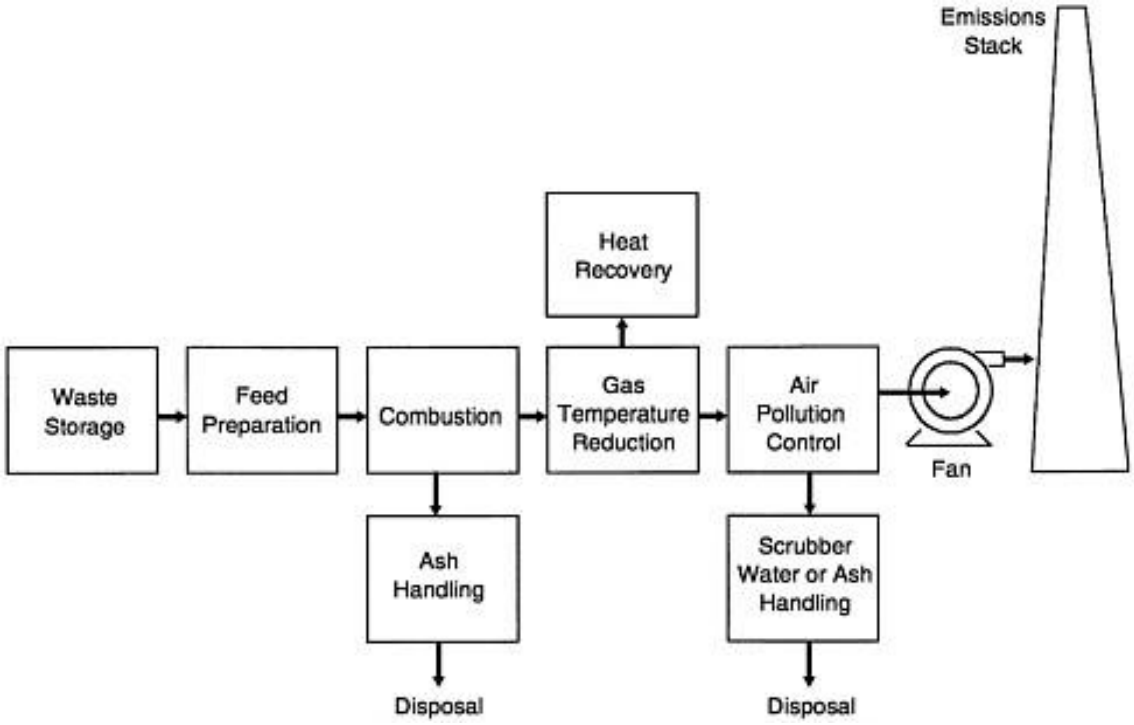

Fig 4. Incineration process

Even these methods have certain disadvantages which are amplified by lack of proper incineration plants: -

a. It is expensive(when done in the correct way)
b. Even the best incinerators are known to produce smoke, this untreated smoke is poisonous and even after treatment, this smoke is known to be a major pollutant.
c. The long-term impacts of these incineration plants, in the communities they are built, is hazardous. It is known to cause diseases like cancer, birth defects, reproductive dysfunction and so on.

2. Waste Collection through IoT

Waste collection itself has been a big issue for all the local authorities, there are two important parts of waste collection, first about waste segregation, this part is tackled by Swachh Bharat Mission where waste segregation takes place at the source (usually at household). The second and tougher part of waste collection is optimum transfer of collected waste into correct processing plants and centers. For

proper collection and the transfer of horticulture waste the Internet of Things can be used.

a. Optimization of Horticulture waste collection Using IOT

1. **Route optimization using sensors:-**

The loads on disposal units might change from day to day, week to week, and season to season. Summer garbage loads, for example, may be smaller in bulk, lowering the requirement to collect more frequently than during the winter season. A sensor can be attached to a dumpster by municipalities or garbage management businesses to measure its fill level. These "smart" dumpsters may then provide waste collectors real-time fill level information. Using this information, the IoT system can determine the best paths for garbage collectors to take in order to prioritise regions in need of cleanup while avoiding disposal units that still have space. This results in a more efficient pickup operation that ignores empty trash containers, saving both gasoline and manpower.

A real-world example:-

Evreka, a Turkish company that provides unique waste collection solutions and works with municipalities around North America and Asia, is one real-life example. They put heat, shock, and water-resistant sensors on garbage cans. These sensors collect information such as location, temperature, and fill ratio and send it to the main cloud servers, which may then be utilised to optimise truck routes, estimate the frequency of visits required, and fill levels.

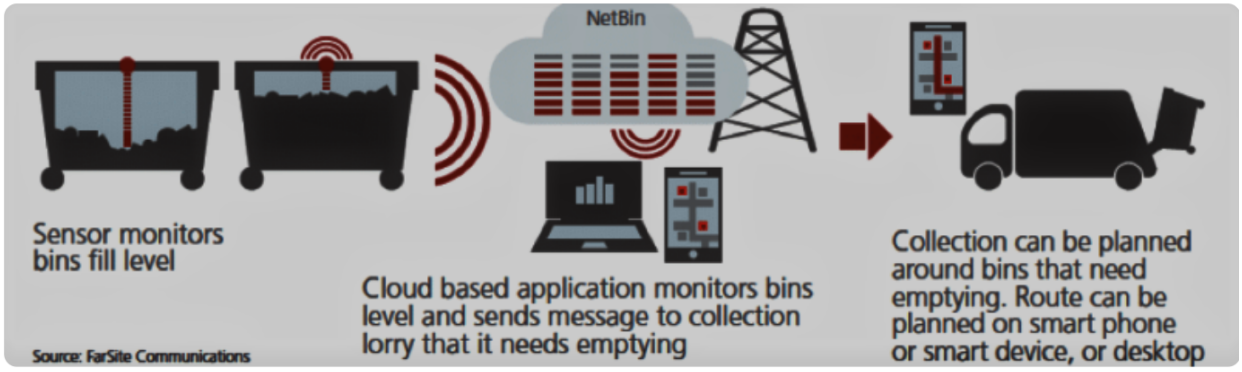

Fig 5. Route optimization by sensors

2. Ensuring that there are no missed pickups:-

The information gathered from the "smart" dumpsters also aids in the reduction of missed pickups. When a dumpster is about to overflow, the sensors warn the authorities immediately, and pickup vehicles can be booked. This streamlines the waste management process and eliminates trash bin overflow.

'Smart Routes' that consider traffic flows, available workers, collection vehicle size, and other factors to determine the most cost and time-efficient routes to bins that need to be emptied.

- Smart sensors measure the level of waste
- Containers send the information to a data management system of the level of waste or last collection.
- Only certain bins are marked for collection.
- Trucks only collect full or overdue waste containers

It is also crucial because currently, trucks have to stop at every bin to check whether the waste from that bin should be collected or not, this makes the entire process not just inefficient and costly but also results in greater fuel consumption and hence greater emissions.

The knowledge of waste amount in bins can also help us decide which bins should be replaced by bigger bins and in which areas there is lesser waste collection.

B. The use of IoT to enable efficient data analysis and collection:-

The connected gadgets keep track of how many times the bins are emptied and how quickly they fill up. When this data is paired with information from other smart city technologies, IoT can prove its worth. The possibilities are seemingly endless: better garbage bin distribution, elimination of improper disposal techniques, and reduction of waste sent to landfills.

Real-world example:- Compology Inc., situated in San Francisco, tackles the waste management problem by collecting data. The company collects data from waste bin sensors, which are then analysed and presented using web-based software. Compology's system measures and anticipates the degree of fullness in waste containers, allowing waste carriers to schedule and route trucks to empty just the containers that require care. Compology gives garbage carriers access to data and insights that help companies fix inefficiencies while also improving customer experience.

C. Representation of benefits of using IoT

Fig 6. Benefits of IoT in waste management

Using Sensors and IoT platforms, companies and cities can realise several advantages, including:

Reduction in collection costs: Smart waste bins transmit their real-time fill level information to waste collectors. The IoT solution uses the data and selects optimum routes for waste collection trucks. This leads to a pickup process which doesn't consider empty waste bins, saving fuel as well as manpower.

No missed pickups: Unlike traditional collection methods, the smart waste management process eliminates the overflowing of trash bins. When a trash bin is about to get full, the authorities are immediately notified. And collection trucks can be scheduled for a pickup even before the pre-scheduled time.

Waste generation analysis: Smart waste management is not just about route optimization. It is said that the real value of IoT lies in data analysis. Most of the IoT solutions available in the market are coupled with data analytics features. Such capabilities can help waste management companies predict future waste generation.

Co2 emission reduction: There has been a lot of discussion and debate about the carbon footprint of waste management and recycling. Optimized routes lead to less fuel consumption, which ultimately reduces the carbon footprint, making the waste management process more eco-friendly.

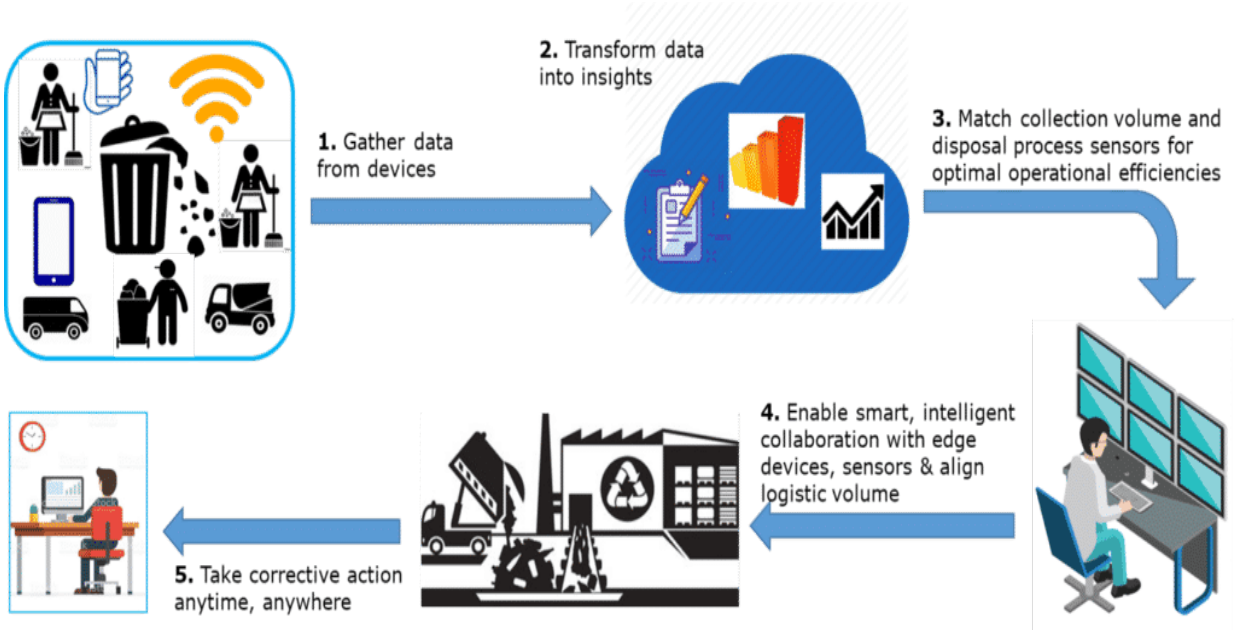

Fig 7. Data collection and analysis after use of IoT in waste management.

Bin sensors: measure the filling rate of waste bins. As a result, we know how full the bins are in real-time, and only full bins can be selected. The result is a task to empty the full or nearly full bins rather than all the bins including those that are nearly empty because it is well planned.

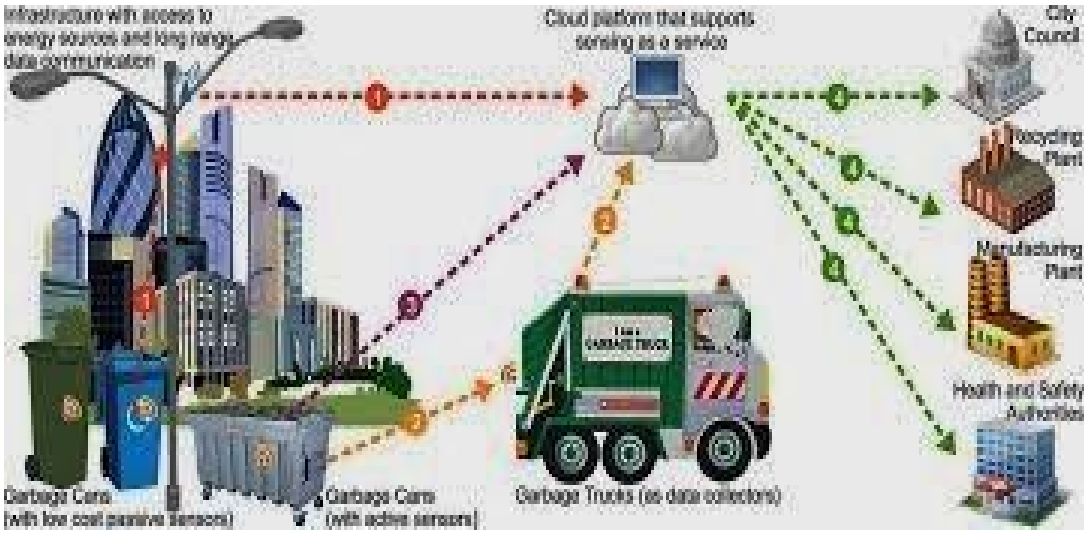

Fig 8. Data flow in IoT waste management system

Managing waste collection through Sensor Based Smart Waste bins:

- It will stop the overflowing of waste bins along roadsides and localities as smart bins are managed in real time.
- The filling and clearing time of smart bins will also be reduced thus making empty and clean dustbins available to people.
- It also aims at creating a clean as well as green environment.
- By using the route algorithm it will smartly find the shortest route thus it will reduce the number of vehicles used for garbage collection.
- Send optimised routes directly to drivers.
- It will reduce truck fuel Consumption.
- Less amount of fuel consumed by vehicles thus can save a large amount of money as well.

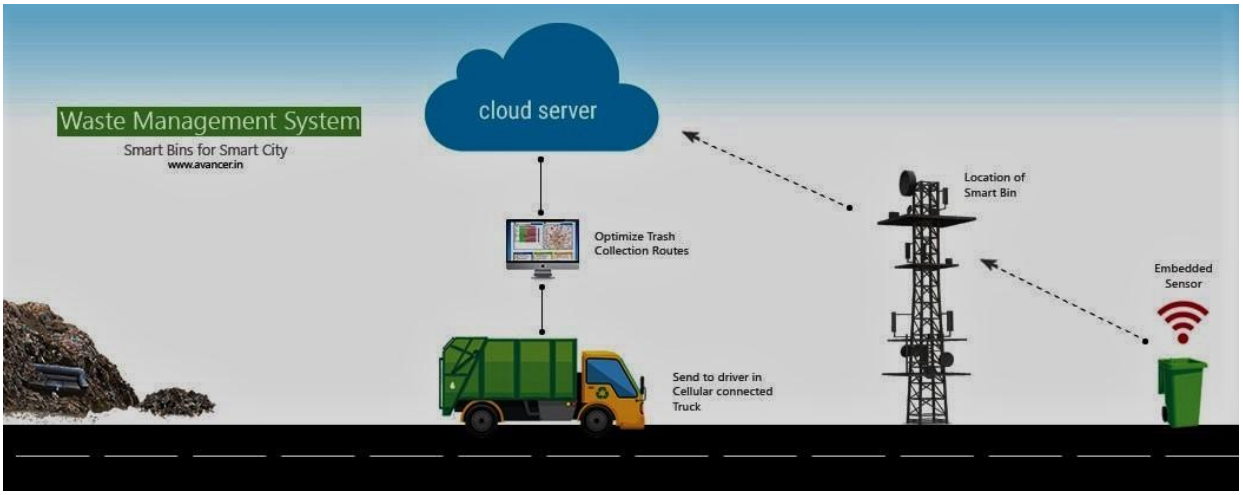

Fig 9. Use of smart bins for optimizing collection routes

D. Implementation of Smart Waste Management using iot -:

Both private waste management companies and municipalities can benefit from intelligent waste management technology. With the reduction of the costs of sensors and the widespread use of sensors. all waste management services can manage waste in cities with operational efficiency and lower costs.

Wireless technologies developed to make our business more efficient and smarter are becoming widespread and consequently their costs are gradually decreasing. When materials considered as garbage or waste by people are evaluated, they can become products that add value to the economy. These technologies, which allow us to produce unlimited innovative ideas, are easily applicable for the control, recycling and protection of our waste.

The IoT technology category focuses on the devices adopted to record and transfer information such as:

- **RFID tags** – used for bin tagging and identification
- **Near Field Communications** – adopted for transferring the data in the infrastructure.
- **Sensors** – fundamental component of IoT-enabled waste management, they measure a set of physical quantities such as: capacity, weight, temperature, humidity, chemical reactions, and pressure
- **Wireless sensor networks (for large scale communications)** – adopted for transferring the data in the infrastructure. Applied on top of sensors that interact wirelessly with each other and the network components.
- **Actuators** – Used to interact with the waste bins, for example, locking the bin lid when its full.
- **GPS** – Incorporated on the collection trucks. Essential for location tracking during dynamic routing.

Software Analytics

The software analytics category focuses on understanding your waste and making data driven decisions:

- **Dynamic scheduling** – Defining the exact time where a trucks' routing process will be initiated.

- **Dynamic routing** – Real-time changes in the pre-defined route to better serve the needs of ongoing waste management.

It also involves:

- **The architecture** – Identifying where bins, trucks, depots, dumps, are located and creating an efficient routing system based on this data.
- **The social context** – describes the dynamics and social impact of waste management on citizens.
- **The experimental data** – Used for evaluation of the proposed solutions.

For example, by using software analytics you can uncover a plethora of useful data which proves that dynamic routing is more efficient than the current routing procedures we have today.

3. Waste Management

a. Green waste reprocessing

A new innovative reprocessor for horticulture waste is GWR which is an abbreviation of **Green Waste Reprocessor.** (To manage garden level waste like flowers, grass, pruning waste, twigs etc.)

Green Waste Reprocessor for Green Rejects / Horticulture Waste:

A new innovative reprocessor for horticulture waste is GWR which is an abbreviation of Green Waste Reprocessor. The best thing about this machine is that it is installed close to the point of waste generation, thereby, saving the burden of transporting the waste from the point of generation to the treatment site. Easy to install, it requires small space to set up and can be successfully operated by employing 2 or 3 semi-skilled laborers. Green Waste Reprocessor recycles the horticulture waste into rich compost which can be used to fertilize the farmland in an organic way. True, a city might require dozens of Green Waste Reprocessors to successfully reprocess the total horticulture waste, but only a decentralized model of dealing with waste can solve the problem effectively on a sustainable basis.

The pace of urban plantation is commendable and has started showing its result in visibly increased urban green cover as well. A huge amount of horticulture waste generating from parks, forests, private gardens, vegetable markets, temple flowers, hotels, hostels, industrial catering unit etc. needs to be managed in such a way to creates minimum pollution.
Green Waste Reprocessor (GWR) machine unit has very small size of 10'x10'x10' with less than 4 ton of weight. The unit is capable of reprocessing up to 3 MTD of horticulture waste on site.The end product is a solid biomass, and liquid compost for various usages, primarily in energy and organic manure. GWR is a one stop solution for 'Total Elimination' of the entire organic reject at the place of its generation. The by-product of this machine can be used for green energy solutions. Once the capex is met for the installation of unit, the entire operation is self-sustainable. The unit is capable of recovering the cost of manpower.

GWR unit was procured by CPWD and Horticulture Department, NDMC for their green
waste to manage the green waste at source in decentralized manner. GWR unit is presently available in 3 different variants for re-processing different types of wastes viz. Vegetable mandi waste, Temple waste and Garden waste (Horticulture waste).

Process: The plant works in reprocessing mode to take continuous input and gives continuous selectable output. Manual worker segregates all inorganic materials from input content and put into a bin ready to go at machine input. Worker put input content at hopper by checking the right mix contents to maintain moisture balance. It takes load of more than 2 ton per day in 8 to 10 hours at top loading input hopper manually feed through stairs. Sensors inside reprocessor unit check and maintain right moisture into granules and tiny particles at input and process within by providing right temperature and steam into all content therein. There is provision of optional add-on-content also. Since one section of processor works continuously, and other section of processor works in interruption mode to allow

timings to worker to provide input and works to conserve electricity as well. Within this time, processed output is available at reprocessor output to feed into low noise densifier unit, through operator friendly AQC unit to control and minimize the frequent trip time of advanced densifier and to minimize the operational load of operator, with help of sensor controlled electronic modules.

Design: Low electricity consumption, low noise during operation, steam router, fully automated control panels, by product weighing mechanism, biometric system based
operation are some of the aesthetic and user friendly elements in the designing aspect of the plant. All above component are made of different grade of stainless steel, galvanized steel and mild steel, and durable indigenous components, are assembled on rigid & strong structure and whole assembly are compacted into soundproof enclosure aesthetically. Regular operation and maintenance assure its long life.
Utilisation: The machines are required by all PWD/ Corporations/ CPWD/ Development
Authorities of all States/ Cities. All of them have a separate horticulture department which faces major issues. Most of the big parks are managed by these bodies and any big park shall require a machine to re-process green waste. At the same time, if parks are small enough then one machine can take care of all the parks in a colony and RWA's can be utilised to make sure all green waste is re-processed. At the same time this solution can be implemented by Agriculture Mandi's/ Food Parks, Cow Sheds, and Big temples as a lot of vegetable waste, cow-dung, and flower waste is available from these places respectively.

Costing: While the machine is self sustainable in itself and the sale of produced energy
sticks/ compost shall make sure that project breaks even in 5 years, additional benefits like employment, reduction of dependance on fossil fuels, drastic reduction in landfill requirement area, carbon credits etc are some of the advantages which cannot be quantified. One machine costs approximately Rs. 30.0 lakh which includes first year of operation & maintenance, and 1 year warranty.

Fig 10. Green Waste Reprocessor machine.

CASE STUDY ON GWR-

- **Background-**

Clean India Ventures Private Limited (CIVL) is an effort to bring a radical shift in treating our surroundings and wastes. The company is up in arms against the severe problem of garbage. Its revolutionary and much appreciated product Green Waste Reprocessor (GWR) has been duly designed to recycle and minimize the organic waste. Its breakthrough technology upcycles most of the organic waste like Garden Waste, Temple Waste, Kitchen Waste and Mandi i.e. market Waste into Organic fertilizer i.e. Compost and also into Liquid Fuel. The byproduct of the treatment which is very aptly named as Earth Life, is very popular with people who are really environment conscious.

Out of the total waste that is generated, almost 60% is organic. Most of this is transported to landfill sites which contaminate underground water, or burnt which produces greenhouse gases like methane. Reducing the necessity for heaps of organic waste to be transported and eliminated in such a way, the Green Waste Reprocessor Machine (GWRM) manufactured by Clean India Ventures reprocesses all types of organic matter into compost at the source of waste generation. This not only solves the problem of waste treatment but also produces useful fertilizer.

Clean India Ventures is a subsidiary of MAPPS group, which envisions diversifying and consolidating as a conglomerate of multiple businesses with the mission of bringing different expertise under one identity.

Objective of the assignment-

The objective of the projects is to provide a better solution in the field of waste management along with creating value for the users.

• Vision: "To be regarded globally as an innovative and highly sustainable organization, creating a greener today and tomorrow."

• Mission

: "Create innovative solutions towards a better tomorrow for everyone."

• What was done-

In 2015, the founder envisioned the project and started developing the models in Delhi. "While everyone keeps emphasizing the fact that India needs good technology to accelerate its waste management process, there are many home-grown entrepreneurs who need ecosystem support to do wonders," he says. With this as an aim, Clean India Ventures is attempting to create an ecosystem where all organic waste is reprocessed at the same site, This case study was curated by the India Sanitation Coalition eliminating the need of transportation and landfilling. While there are many such organic waste treatment ways, Clean India Ventures' solution stands out. This one of a kind machine is installed at the root of waste generation with zero need to transport as transportation adds even more pressure on earth. Dumping the already stretched landfills can be put to an end. Moreover, the added advantage of a repurposed end product i.e. the fertilizer is like an icing on the cake. Initially available in different capacities, to meet various requirements, this machine is successfully operating at various locations in Delhi-NCR. As time elapsed they are planning to operate across the nation.

Below are other products developed by CIV:

• Organic mixed waste reprocessor: Treats mixed waste that is produced by daily activities.

• Tempe waste reprocessor: Produces liquid fertilizer; treats Havan samagri made from flowers.

• Garden waste reprocessor: The machine consumes dry leaves & tree branches from parks on the roadside & forests to produce fuel sticks which provide smokeless energy. Organic Manure can also be produced.

• Cow dung reprocessor: Processes cow dung to make fertilizer, reduces methane

• Green waste reprocessor: Treats green waste like vegetable waste, wet garbage etc.

• Vegetable waste reprocessor: The machine produces solid animal feed, liquid fertilizer and organic Manure/Compost.

CVI has named their product as 'Earth Life', which is packed compost prepared by reprocessing green waste through GWR. Besides marketing GWR, Clean India Ventures also markets Earth Life.

• Impact-

CIVL has successfully installed 8 projects across Delhi, Haryana, Punjab, Rajasthan. While most of them are on paid basis, some are done as trial projects. This is done for the satisfaction of authorities, foreseeing that sooner or later they will switch to the paid model. The impact is huge- societal, economic, and environmental.

• Proper waste management makes the environment and prevents spread of diseases.

• There is a considerable saving in the cost of waste treatment.

• The reprocessor creates compost which can be used as fertilizer.

• It reduces emission of harmful gases such as methane; the environmental contribution of this project is appreciable.

• Challenges and Issues-

Whenever the team has presented the idea, it has been appreciated warmly. But there is a resistance among corporations and private owners to spend on waste management as everyone thinks it is not their responsibility. With importance given to the cost factor, many government bodies shy away from participating in the initiative. This has resulted in a slow growth rate of the project.

But, the CIVIL team is working hard to bring change in this mindset of people. The team is targeting the fact that people fail to see their current expenses on

transportation. CIVL has identified organizations willing to adopt their systems, but are unable to so because of bureaucratic rules in the organizations.

• **Innovation-**

GWR is fully capable of changing this dismal scenario. The low cost and easy-to-operate GWR reprocesses the waste effectively, employing 4 – 5 semi-skilled workmen which can be hired locally, giving employment opportunities. If a city or a village replaces its waste-carrying truck fleet with GWRs, it would have a revolutionary effect on environment and expenditure without affecting employment. Below mentioned are the innovations that CVI brought and implemented:

• Horticulture Waste Model

• Agro-Mandi Waste Model

• Organic Mixed Waste Model

• Temple Waste Model

• **Lessons learnt-**

Awareness about the situation is a key in such projects because segregation and treatment of waste at source is the future. This is a critical problem as people are not yet aware why waste should be segregated at home. Once India starts waste segregation at home, it shall go a long way in helping the country reprocess its waste well.

Economic sustainability/Revenue Model-

The low cost and easy-to-operate GWR reprocesses the waste effectively employing a maximum of 4 – 5 semi-skilled persons. Generally speaking, if a city replaces its waste- This case study was curated by the India Sanitation Coalition carrying truck fleet with GWRs, it would have a revolutionary effect on environment and expenditure without affecting employment

APPLICATIONS-

1. **The waste reprocessor at the Nigambodh ghat in Delhi-**

A Green Waste Reprocessor (GWR) was inaugurated at **Nigambodh Ghat** on the banks of the Yamuna River, one of the oldest burning ghats in Delhi by environment minister Harsh Vardhan in 2017.

'GWR is a promising machine which will reprocess flowers and leaves that come to the Ghat. Earlier it was either thrown away into the river, or would pile up as refuse which was removed by municipality trucks. Either way it adds to pollution," Harsh Vardhan said. "With GWR, the entire volume of flower waste will be reprocessed on a daily basis. Thereby saving our River Yamuna from Pollution."

The machine can convert 500 kgs of flower waste into havan samagri, which is a coarse mixture of dried herbs, roots and leaves used for feeding ritual fires. The processor that runs on electricity is able to generate havan samagri on the spot which will be distributed free to people performing havans at the ghat.

"Crop burning and organic waste management is a very important issue," Alok Gupta, director of Clean India Ventures, the company that makes and runs these processors, said. "This processor allows treatment in a decentralized manner."

The company has installed 8-10 waste reprocessors in Delhi NCR and a few neighbouring cities like Ajmer, Pathankot and Faridabad. The machines, whose capacity can range from 100 kgs to 4000 kgs, can process organic waste from mandis, ghats, hotels temples.

A CPCB report found that water quality at holy sites along rivers where large numbers of people congregate tends to be poor. Organic waste is easier to recycle and reuse that treatment of sewage water, another source of water pollution.

Clean India Ventures also plans to use the processor to convert crop residue into compost. Crop burning is a major contributor to particulate pollution in the northern region especially during winters.

The Indian government is exploring options like production of bioethanol and the mixing of crop residue pellets with coal for power generation.

"We have to try multiple things, it is possible that in Haryana 10 districts have a different solution and 5 have a different solution," CK Mishra, environment secretary told the HT in a recent interview. Punjab, Haryana, Uttar Pradesh and Rajasthan see crop residue from the kharif crop piled up and burnt every winter.

b. Go clean composter

GoClean Composter Machine (earlier GWR) is designed to process organic waste with its intelligent technology. The GoClean Composter Machine maintains a right balance between temperature, air flow and moisture with right proportions of heat, salt and acid resistance.

The unit is capable of reprocessing from 50 kg per day to up to 2 MTD of organic waste on-site. We have multiple by-products according to the type of biodegradable waste we get. The unit is capable of recovering the cost of manpower. The plant works in reprocessing mode to take continuous input and gives continuous selectable output. Workers segregate all inorganic materials from input content and put them into a bin. The machine also maintains the moisture balance. The machine takes the load of more than 2 tonnes per day at top load. With built-in sensors the machine helps in checking and maintaining the right balance of moisture and steam to process the waste. As the temperature increases, the machine activates the bacteria which help in breaking the organic compost into fertile compost. The machine vaporizes the moisture present in waste and vents through the blower into the drain.

With this technology, there is almost 85% volume reduction in compost formed and also converts organic food waste into 70-80% mature compost within one day. Machine also maintains the temperature and air flow to prevent the odor and pest problem.

GoClean Machine is a complete environment friendly machine with no leachate and no emission of harmful gases.

We can also customize the GoClean Composter machine according to the client's requirements and size availability. We have our in-house manufacturing facility catering to client's requirements.

Fig 11. Go clean composter spread all over the India.

c. Aerated static pile composting

HISTORY:

Indore Composting: In 1931 Wad and Howard invented a systematized procedure for composting in Indore, Madhya Pradesh (Fitzpatrick, 2005). This is an aerobic method which can turn organic waste such as garden waste, wood ashes, animal dung, and bagasse, sawdust, and night soil into good quality compost in less time compared to the anaerobic method In this process of night soil and vegetable, waste is piled in alternative layers in the depth of 7.5-10 cm each, the overall depth of 1.5 meters above the ground is maintained .this method takes 4 -5 months (Mishra et al., 2003) and during this time the aeration is provided by turning the pile. The NPK concentration is 0.8%N, 1.0-1.5%K, 0.3-0.5%P.

Bangalore Composting: In 1939 Acharya had come up with a composting technology for night soil and town litter that is the Bangalore method of composting (SBMG, 2015). This is an anaerobic method and also known as the hot composting method. Urine, plant leaves, garbage, animal manure are used as raw feed. Earthen trench of about (10m×1.5m×1.5m) is filled in layers of waste and then covered with a 15cm soil layer. Within week waste started to decompose because anaerobic microorganism starts their work after 4-5 months fine brown color stabilized matter compost is ready for use.

But these technologies are time consuming, and in 1970's USA came up with an efficient solution with some new machinery uses (like blower etc.)

MODERN TECHNOLOGY:

ASP composting was originally developed by the U.S. Department of Agriculture in the mid-1970's and is used throughout the country to process a wide variety of municipal organic waste materials. We have simply taken this technology and adapted it to work with smaller volumes of organic waste materials in various on-site settings, including agricultural, industrial, municipal and institutional (e.g., universities, military bases, prisons, etc.).

Aerated Static Pile (ASP) composting, refers to any of a number of systems used to biodegrade organic material without physical manipulation during primary composting. The blended admixture is usually placed on perforated piping, providing air circulation for controlled aeration (**Aeration is the process by which air is circulated through, mixed with or dissolved in a liquid.**) . It may be in

windrows, open or covered, or in closed containers. With regard to complexity and cost, aerated systems are most commonly used by larger, professionally managed composting facilities, although the technique may range from very small, simple systems to very large, capital intensive, industrial installations.

Aerated static piles offer process control for rapid biodegradation, and work well for facilities processing wet materials and large volumes of feedstocks. ASP facilities can be under roof or outdoor windrow composting operations, or totally enclosed in-vessel composting, sometimes referred to as **tunnel composting.**

OBJECTIVES OF ASP COMPOSTING-

In designing our compost systems, our primary objectives are to:

1) protect surface and ground water resources;

2) reduce the time and expense now committed to manure management;

3) produce a high-quality finished product for use around your farm, local community gardens, or to sell to gardeners in the area.

With aerated composting we maintain aerobic conditions throughout the compost pile and are able to control pile temperatures. This, in turn, expedites the composting process and yields a high-quality compost product that is effectively free of pathogens, parasites, and weed seeds. By composting in this manner, we are able to control offensive odors and flies, improve the aesthetics of the waste handling area, quickly produce a superior product and reduce the cost of labor and equipment (i.e., fuel, maintenance, etc.).

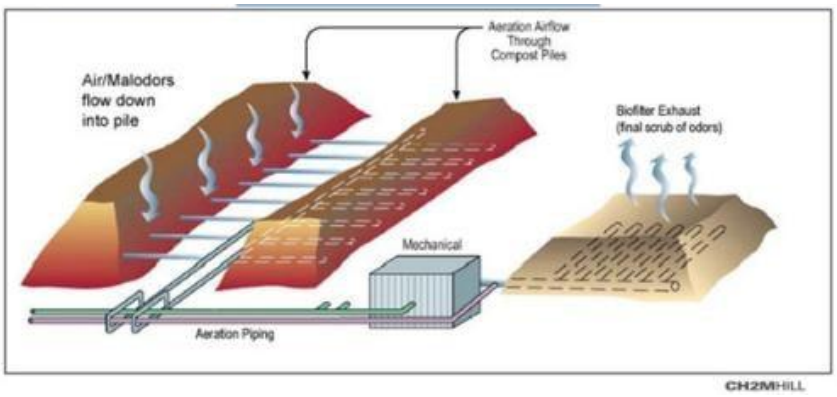

Fig 12. Aerated static pile

How Aerated Static Pile Composting Works-

The system consists of a triangular pile that is twice as wide as it is high with a French drain-type pipe embedded in the pile. This pipe allows for both positive and negative pressure to help with the aeration process. Pile size is normally dictated by how often new raw materials are added. The aeration process leads to quicker composting than in a windrow system because the operator has greater control over the amount of oxygen that goes into the pile. A static aerated pile requires less area and work then windrows and the active composting period normally takes from 3 to 5 weeks to complete. Just like windrows, extra height is advantageous during the winter to retain heat. A filtration system may be necessary to filter the air when the aeration system is using negative pressure to pull air through the pile.

In the most basic terms, an aerated static pile has 5 components:

- **a blower** connected to a timer or to a temperature sensor which triggers the blower fan
- **a manifold** to deliver the air, often with PVC pipe with perforations or holes to allow the air to enter the pile
- **an air plenum layer** to diffuse the columns of air escaping from the perforated PVC, ensuring a uniform distribution of air into the bottom of the pile
- **an active layer**, comprised of the base material intended to be composted
- **a biofiltration layer**, often comprised of mulch, compost, or even very expensive Gore covers. The bio layer traps heat and odors and protects the active core from birds, rodents, and other vectors.

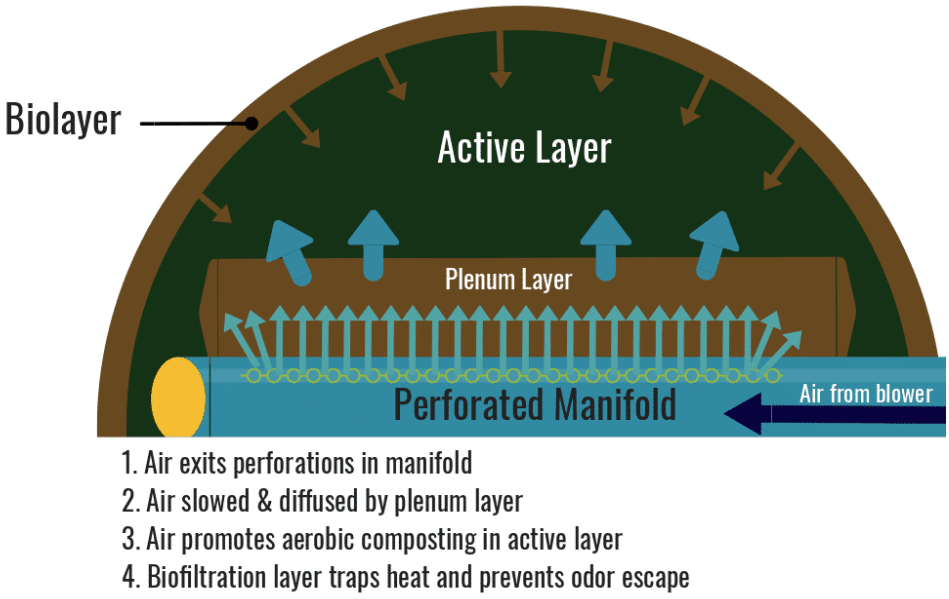

Fig 13. Working on the aerated static pile composting

Materials and Methods-

1. Raw Material- Yard waste (144,520 kg) was crushed in a hammer mill with a screen of 7.5 cm and mixed with food waste (149,690 kg) from industrial canteens and the food industry.

2. Positive Aerated Static Pile (ASP) Construction- The pile formation was carried out with a front loader on a network of perforated pipes.

Fig 14. Pipe network for the ASP

This pipe network was made up of a 6-inch tube, 4.5 m long that fed air to 4 pipes, each 24 m long, joined by a reducer coupling [2]. The air supply was provided by a 2 HP blower with a maximum air volume of 40.49 m3 /min (B-Air super bear BP-2+). The perforation of the tubes consisted of two rows of perforations, 0.95 cm per hole, placed in parallel to each other, 5.8 cm from the surface of the tubes. The

distance between perforations was 15 cm [3]. Before the formation of the pile, a layer of reject material (15 - 20 cm, 1 cm opening screen) was placed on the ground level of the composting screening process. With this same material, the tubes were covered with perforations downwards with a layer of some 15 cm before forming the pile [2]. Since the raw material was not enough to form a projected pile of 10 m wide, 24 m long and 3 m high in a single stage, the first two tubes were covered in the first stage and then 7 and 14 days later were covered the third and fourth tubes respectively. At the end of forming the pile in its three stages, the material was covered with an approximate layer of reject material (15 - 20 cm). For the measurement of temperature changes, as the pile was formed,16 thermocouples were placed along tubes 1, 2 and 4 and along the tube 3, 4 thermocouples were located, one half of them at an approximate height of 1 m and the other at a height of approximately 2 m. At the end of 7 weeks of composting for tubes 1 and 2, 6 weeks on tube 3, and 5 weeks on tube 4, approximately 62 m3 were taken to form a curing pile. The rest of the material completed the process under the windrow composting method (three windrows of 65 m long, 1.75 m width and 1.10 high) with a tractor-assisted windrow turner.

3. Curing Pile- A portion of the ASP material was screened through an aperture mesh of 2.54 cm, and used to form a pile of approximately 62 m3 (2.44 m in height and 9.86 in diameter) for the curing period. In this pile, 5 heavy duty compost thermometers (60 cm steam) were placed in different places to measure the temperature over 44 days. At days 3, 6, 8, and 16 of maturation, composite samples were taken for moisture analysis, turning and moistening the pile the next day. On days 24, 28, and 31, the pile was turned over and composite samples were

taken for moisture analysis without having moistened the pile the next day.

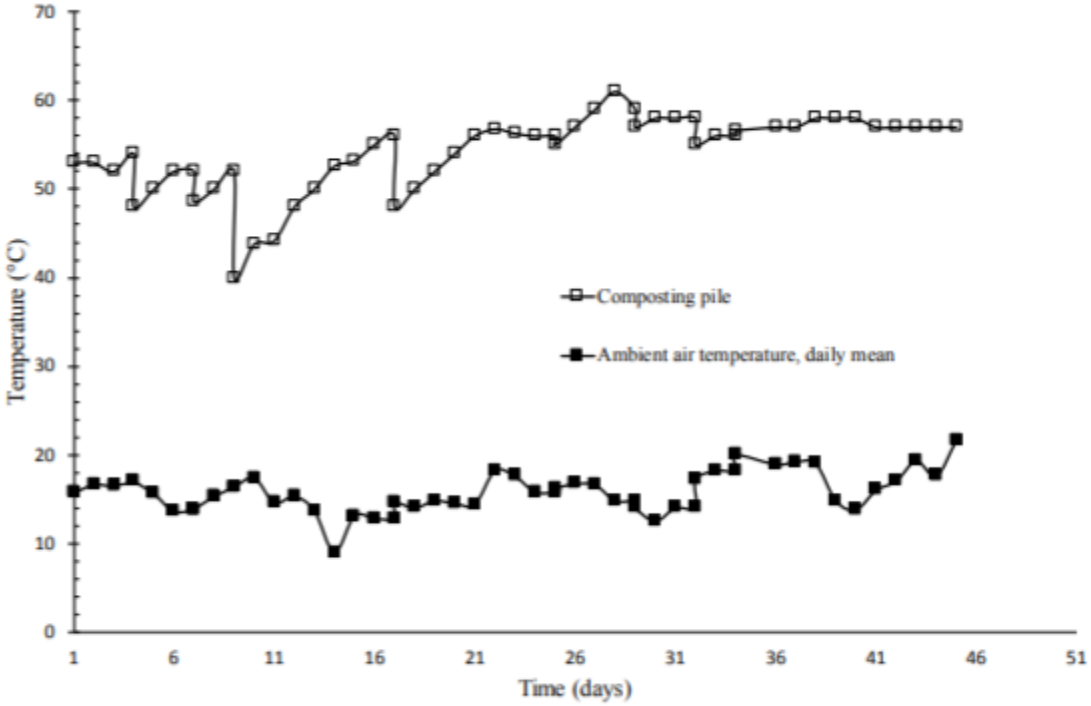

Fig 15. Temperature profiles of the composting pipe in the curing period

After 44 days of curing, a composite sample was taken from the pile for the maturity analysis, seedling emergence, and relative growth [4] and stability [5].

4. Physico-Chemical Analysis- At the beginning of the pile formation, the mixture of yard and food wastes was analyzed by its content of moisture, total organic carbon (TOC), total Kjeldahl nitrogen (TKN), dry matter, ash, volatile solids, bulk density, and free air space. Moisture content (%ww) was determined after drying to a constant weight in a ventilated oven at 105˚C for 24 h. Volatile solids (%dw) was determined by the percentage ignition loss of dry solids at 550˚C in a muffle furnace (Terlab). TKN was determined by the macro-Kjeldahl procedure [6]. TOC content was calculated by the following equation [7]:

%TOC = (100-% ash residue)/1.8

Bulk density refers to the ratio of the total weight (mass) raw material or compost to its volume, on an as-is basis that was calculated as follows: an empty 20 L bucket was weighed (recording the weight) and filled 1/3 full with feedstock. The bucket was raised 1.5 m above a firm surface and allowed to drop 10 times, then the bucket was filled to the 2/3 line with additional material and raised 1.5 m above the surface and dropped 10 times. The bucket was then filled completely and the

dropping sequence was repeated. The bucket was refilled completely (without dropping) and weighed with the material. Bulk density was reported as kg/m3 . To measure free air space, the same bucket and materials were used. This test uses water to approximate the amount of voids (free air space) in a bucket full of feedstock. The bucket was filled with water completely without overflowing and weighed. The free air space expressed in % was calculated as: (L of water that filled the spaces) (100)/volume of the bucket in L [8].

Benefits of Using the ASP Method

#1: ASP Composting Eliminates the Need to Turn the Compost Pile-

By inducing airflow into the compost pile, we are able to maintain aerobic conditions, manage pile temperatures and expedite the composting process to complete the Active Phase in approximately 30 days.

#2: ASP Composting Dramatically Reduces the Cost of Composting Operations-

By not having to turn the piles with either a front-end loader or a specialized windrow turner, the operator dramatically reduces the cost of fuel, labor and equipment maintenance.

#3: ASP Composting Significantly Reduces the Amount of Water Consumption during the First 30 Days of Composting-

When compost piles are turned, a considerable amount of moisture is lost to the atmosphere. ASP Composting has been shown to reduce water consumption by 60 to 75 percent (Reference: City of Bakersfield, CA informal study).

#4: By Using a Compost Cover Layer, You Will Greatly Reduce the Generation of Offensive Odors and Mitigate Offsite Impacts to Neighbors and Passersby-

The cover layer (~12-inches of finished, unscreened compost) serves as a biofilter to absorb odorous gases. The microorganisms that reside in this outer layer digest these compounds in-situ and retain valuable nutrients in the finished compost product.

#5: ASP Composting Eliminates Pathogens, Parasites and Weed Seeds in Three Days-

This same compost cover serves as an insulating blanket to ensure that all raw feedstocks achieve temperatures that equal or exceed 55oC (131oF) for a minimum of three days. These are the federal criteria for a Process to Further Reduce Pathogens (PFRP)

#6: ASP Composting also Reduces Emissions of Volatile Organic Compounds (VOCs), Greenhouse Gases and Ammonia-

The biofilter cover has also been shown to retain a wide spectrum of VOCs, reducing off-gassing as much as 98 percent when compared side-by-side to a turned windrow process.

#7: The Compost Cover also Eliminates Access to the Raw Feedstocks by Flies, Rodents, Birds and Larger Wildlife-

The compost cover also serves as a vector barrier. If vectors dig into the pile looking for food, they soon realize that it is way too hot to proceed any further. Fly larvae in the mix quickly cook as the pile temperatures rise during the first few hours of composting.

#8: ASP Composting is Well-Suited to all Varieties of Feedstocks, Including: Landscape Debris, Food Waste, Biosolids, Animal Mortalities and all Varieties of Animal Manure-

ASP Composting was first developed in the early 1970s in Beltsville, MD, under a USDA Grant. It was initially used for composting sludge from wastewater treatment plants (now called biosolids).

#9: ASP Composting is Well-Suited to all Scales of Operation, from 2.5 Cubic Yard Systems to 100,000 Ton per Year Facilities-

Starting with a Micro-Bin (2.5 cy) to test the effectiveness of the ASP Method, a facility can expand by using the freestanding ASP and the extended ASP approaches.

As a result, ASP Composting easily accommodates volume fluctuations during the year and growth of the facility over time.

#10: Extended ASP Composting Greatly Reduces the Footprint of your Active Composting Area-

By eliminating the alleyways and valleys between turned windrows, the footprint of the active compost area can be reduced by as much as 75 percent for a given volume of feedstocks. For this reason, and because the rate of composting is greatly increased, the flow through capacity for a given facility can be increased by 400 percent or more.

#11: ASP Composting is Easy and Quick to Integrate within an Existing Composting Operation-

An ASP Pilot Project can be easily installed without the need to make any changes to an existing compost operation. When the ASP Method has been fully proven, conversion to this approach can be done all at once or in phases to minimize disruption of the existing operation.

#12: ASP Compost Systems can be Operated Using Solar Power or a Portable Generator-

For sites that do not have access to grid electrical power, solar power (or generator power) is a viable and cost-reasonable option. This is particularly helpful for sites that are located in remote areas or on landfills where the site may change from time to time, thereby making the cost of power installation unreasonable.

#13: Aerated Static Piles and Extended ASPs Can Be Constructed Using Conveyor Systems-

As demonstrated in the Tulare, CA VOC Emission Reduction Study (2012), articulated conveyors can be used to construct very large compost piles, thereby reducing NOx emissions and greatly reducing handling time and diesel fuel consumption.

d. Bio-Methanation

About the process:-

Anaerobic digestion (AD) is a promising technology, which could effectively address the problem of food/organic waste disposal thereby yielding valuable outputs like biogas and fertilizers.In this process, organic fraction of the wastes is segregated and fed to a closed container (Biogas digester) where, in the presence of methanogenic bacteria and under anaerobic conditions, it undergoes bio-degradation producing methane-rich biogas and compost.

The biogas can be utilized either for cooking / heating applications, or for generating motive power or electricity through dual-fuel, gas engines, low pressure gas turbines or steam turbines. The sludge from anaerobic digestion, after stabilization, can be used as a soil conditioner, or as manure depending upon its composition, which is determined mainly by the composition of the input waste.

Plants and tech details:-

Various biomethanation plants can be constructed near waste sources with variable capacity. However the **average capacity of such a plant is around 20Metric tonnes** per day.

The plant involves two process:-

1. **Creation of biogas**

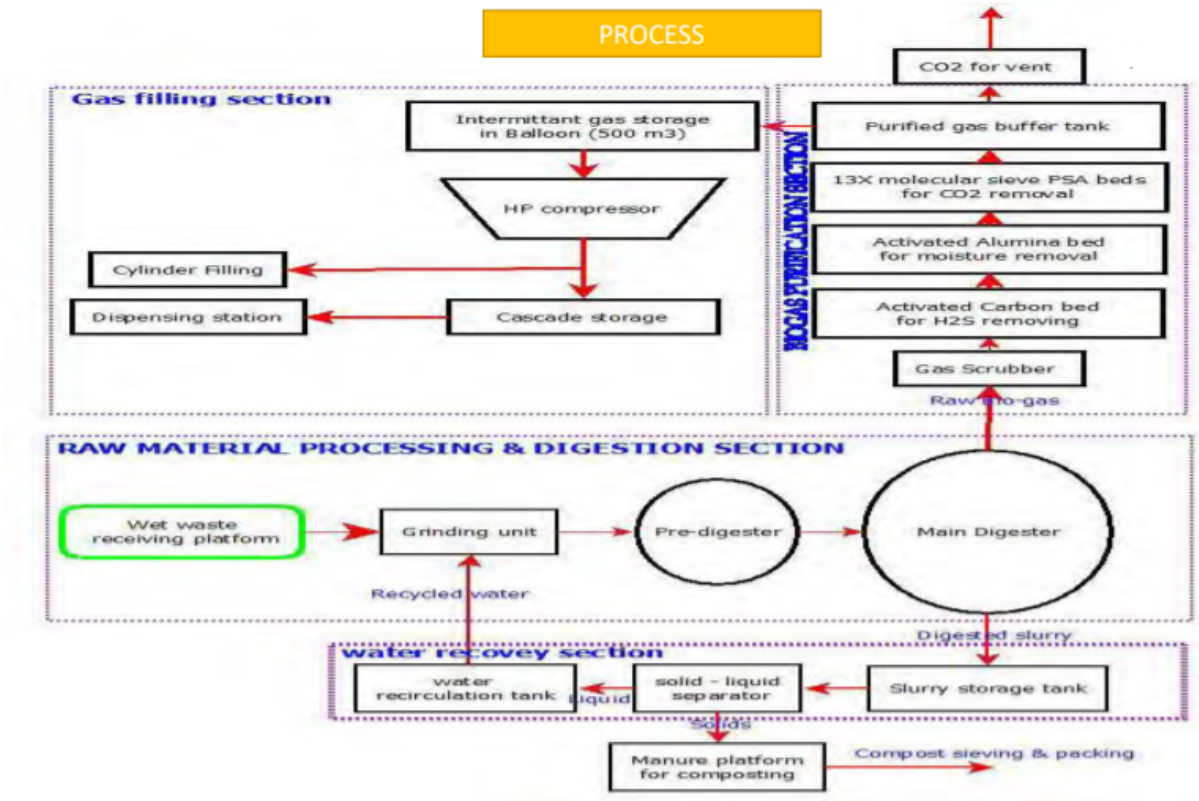

Fig 16. Process of biogas generation

2. **Conversion of biogas to biomethane:-**biogas that has also been cleaned and conditioned to remove or reduce non-methane elements is known as biomethane.

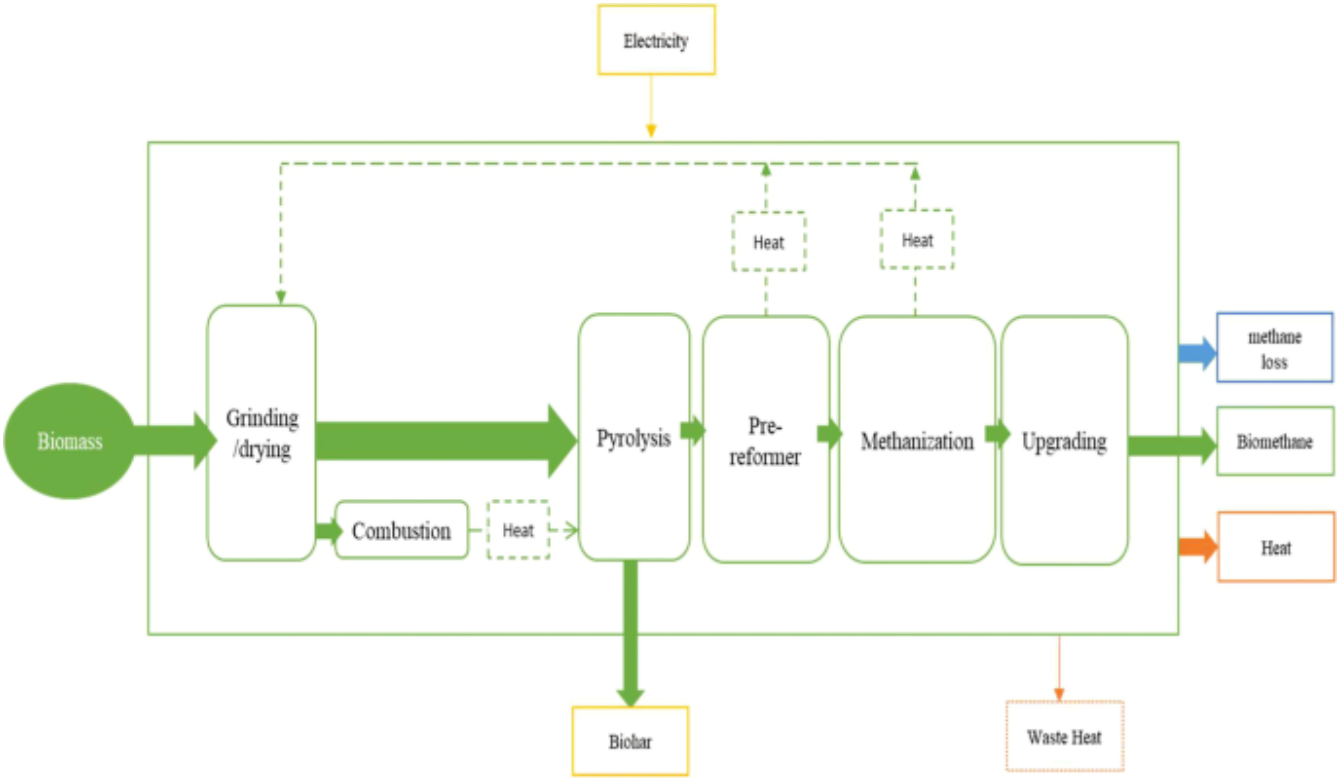

Fig 17. Biogas conversion to biomethane.

Important stages of biomethanation plant: -

1. Pre-treatment: Most digestion systems require pre-treatment of waste to obtain a homogeneous feedstock. For anaerobic fermentation, pre-processing involves separation of non-digestible material either through source segregation (e.g., two-bin system; see Section 2.2 of Part II) or through mechanical sorting at the biogas plant facility. Source segregation results in less contaminated sludge compost. The separation ensures the removal of undesirable or recyclable material such as glass, metals, stones, etc. The waste is shredded before it is fed into the digester for better fermentation especially when the incoming material has large pieces or whole items.

2.Feeding mechanism:- The wet waste which is generated from the vegetable wholesale market(mandis), hotels and schools and from the bulk generators is brought to the biomethanation plant and is kept on the feeding area. Small portions of waste is feeded in the feeder and a grinder is connected with the feeder which grinds the waste to make the processing easy. During the Feeding Process water is added up with the waste in the ratio of 1:1(in 1 kg of waste 1 liter water is added up.

3.Digester:- Under anaerobic conditions, temperature around 35°C and a continuous mixing, biogas is being produced by the conversion of the dissolved organic matters. Daily feeding capacity of 20 Tons. Stirring is done using mechanical, hydraulic or pneumatic equipment. Up to 90% of biogas plants use mechanical stirring equipment. Stirring prevents formation of swimming layers and of sediments, brings the micro-organisms in contact with the new feedstock particles, facilitates the up-flow of gas bubbles and homogenises distribution of heat and nutrients through the whole mass of substrate.

4.Biogas Enrichment:- The raw biogas is processed and purified from the unwanted gases like CO2, H2S and moisture up to a certain required level. If biogas is to be used as renewable source of methane for power generation and vehicular fuel, it should meet with specifications. Biogas up-gradation would mainly involve integration of suitable CO2−CH4 separation facilities.The vacuum-pressure swing adsorption (VPSA) or medium pressure swing adsorption (MPSA) process, which is a subset of PSA, has high potential because here the adsorption step is carried out at near atmospheric pressure, at which the biogas is available, thus negating the high compression cost of PSA.The purification cost is substantially lower than the other technologies with this scale.

5.Purified gas storage balloon:-Bio-CNG Storage Balloon are made with corrosion free double membrane balloon/ holders. The internal membrane is stretched by the pressure of the produced biogas. Air is pumped between the cover dome and internal membrane so that it provides pressure to the upper side of the membrane and gives a spherical shape to the cover dome. A Bio-CNG Storage Balloon, which is collapsible and intermediate storage tank for bio-CNG prior to the application or before compressor.

Various indian cities with such a plant:-

1. Delhi:- in jindal ITF centre on shivaji marg, it disposes about 1/3rd of delhi garbage into clean renewable energy. Delhi govt has entered into public private partnership with jinda urban infra as a legal entity named:- timarpur okhla waste management co pvt ltd.

Firmed which created this plant:- Jindal Urban Infrastructure through its subsidiary named:- jindal urban waste management limited

Fig 18. Delhi biomethanation plant.

2. Indore:- IMC under its policy of promoting decentralized treatment of organic waste established Bio-methnation plant of 20 MTPD capacity. Through tendering process IMC appointed Mahindra & Mahindra Ltd. Mumbai to establish the plant, which was commissioned in December 2017. The overall project cost is Rs. 15.00 Cr out of which Rs. 7.2 Cr. VGF was provided by IMC. The concession period of the project is 15 years.

Firmed which created this plants:- Mahindra and mahindra Ltd.

Fig 19. Bio-CNG plant at Indore.

Expected cost:- for a 20MTPD plant the construction cost can be between 15 to 20 crore based on various factors. There can be also a concession period for which the building company will take responsibility of infra repair and maintenance.

Output of these plants:- the amount of methane generated depends on the quality of waste. However on average 20 cubic metres of methane is produced with 95% purity. This methane can be compressed into bio CNG and can be used as fuel.

Slurry :- The digested slurry is passed through solid liquid separation unit, filtered liquid is used in slurry making and the remaining solid are dried and converted into organic compost.

4. Conclusion

We have concluded that for waste collection and transfer Internet of Things should be used. IoT can reduce the cost of waste collection, enables data analysis of waste collected and makes the entire waste collection process much more efficient. Also, the cost of implementation of IoT in the waste collection is not substantial and hence all the municipalities/ waste management companies should adopt waste collection through IoT. For waste processing among the 5 methods suggested, one method should be used after analyzing the following parameters

1. Quantum of waste generated
2. The cost associated with each plant
3. Available land and manpower for each process
4. Use and concerns associated with byproducts from these methods.

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