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Best Solid Waste Management Practices at Amritapuri: A Case Study

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Abstract--- *Solid waste management, in today's world, has turned out to be a matter of great concern. Rapid urbanization and population explosion have made efficient solid waste management a big challenge for mankind. In these prevailing conditions, Amrita Vishwa Vidyapeetham, Amritapuri campus has designed waste management methods that reduce the burden on urban local bodies by processing most of the waste generated by it, in the campus itself. The paper analyses the various waste management practices like waste sorting, processing and disposal followed in the study area. The paper also explores the scope for further improvements to enhance the overall efficiency of the existing solid waste management system by providing innovative suggestions.*

Keywords--- *Case Study, Best Solid, Innovative Suggestions.*

I. INTRODUCTION

In recent years, there has been an alarming increase in the amount of solid waste being generated, due to unsustainable rates of consumption and production by mankind [1]. According to the United Nations Development Program's (UNDP) Sustainable Development Goal 12: "responsible consumption and production", a target has been set to manage wastes throughout its life cycle and to reduce the impact on the environment and human health, by controlling the release of wastes into the environment [2]. The necessity of managing solid waste in an efficient way is really a matter of great concern in today's world. Improper management of the wastes leads to degradation of soil, contamination of water as well as many health-related problems in human beings [3]. Uncontrolled open dumping is still prevalent in most developing countries which indeed desperately need immediate action, due to the associated harmful impacts [4]. Furthermore, most of the landfills in Southeast Asia are disposal facilities that are not properly designed [5].

There are mainly six steps by which the Municipal Solid Wastes are handled in India, as per the Municipal Solid Wastes (Management and Handling) Rules, 2000 [6]. The first step involved is the solid waste collection process. After collection, the wastes are segregated into different groups which are then sent for reusing, recycling and other processes. The third step involves the storage of the segregated wastes. The waste is then transported in special vehicles, where it is covered so as to prevent it's scattering. These wastes are then processed by different techniques

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of incineration, bio-composting, vermicomposting, anaerobic decomposition, etc. Finally, the wastes are disposed of using proper disposal methods suitable for the type of waste [7].

India, being a country that generates less waste as compared to the other developed countries, is still facing the problem of solid waste management. An efficient solid waste management system that focuses on reuse and recycling can help reduce the pressure on natural resources [8]. It can also help reduce the excessive pollution that has an adverse effect on human life [9]. This study examines the various solid waste management practices that are being effectively implemented in the Amritapuri campus of Amrita Vishwa Vidyapeetham.

II. STUDY AREA

Amrita Vishwa Vidyapeetham is located in the southern part of Kerala in the Indian subcontinent. It is located 119 km away from Cochin International Airport and 82.6 km away from Trivandrum International Airport and situated between latitude 9°06'01.1"N-9°05'15.6"N and longitude 76°29'12.2"E-76°29'37.4"E. The study area comprises of 4 schools and associated hostels built up over an area of 125 acres. The University accommodates a population of around 4000 residential students and 800 staff.

III. WASTE MANAGEMENT PRACTICES

A. Waste Collection and Transport

Waste generated per day on the campus is collected from all the four colleges and transported to the waste sorting center near Amrita School of Engineering. Fig.1 shows the quantity of waste collected from the college on a monthly basis. It is observed that solid waste collected usually spikes in the months of May and December, which is towards the end of the semesters, as the stationary wastes are generally cleared out during this period. The waste generated in the hostels is usually collected once the students leave for their classes. Fig. 2 illustrates the quantity of waste collected from both the boy's and girl's hostel. The quantity of waste collected from the boy's hostel is higher due to a higher number of inmates when compared to the girl's hostel.

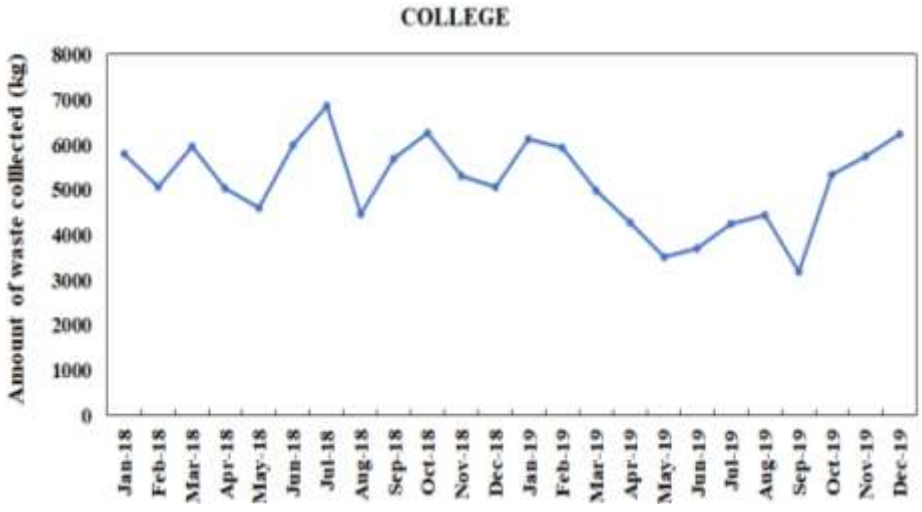

Fig. 1: Quantity of waste collected from the college

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The peaks observed in Fig. 2 are in the month of June, which is at the beginning of the academic year, when all the discarded materials, like bedding and clothes in the hostel rooms, are cleared out. The waste received at the collection center is then sent for sorting and for further processing to the recycling center or organic garden located along the coastline. The waste is usually collected at least twice a day to prevent the breeding of flies and other pests. One of the factors that determine the frequency of waste collection is the odor emanation that occurs due to the decomposition of the accumulated waste.

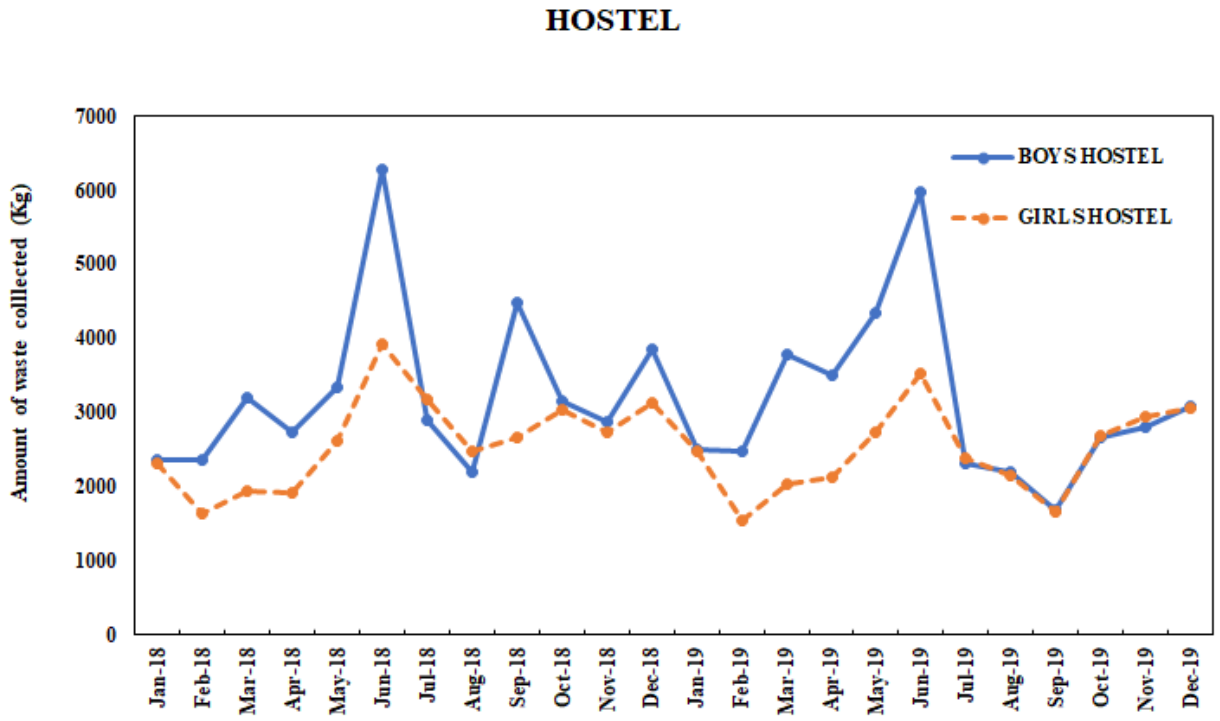

Fig. 2: Quantity of waste collected from Hostels

The waste collected is primarily divided into two types, compostable waste and non-compostable waste. The compostable waste collected is transported using separate trucks to the Kuzhithura organic garden owned by Amrita Vishwa Vidyapeetham. Whereas, the non-compostable waste is transported to the Amrita Sagar Recycling Center. The compostable type includes garden waste and food waste collected from dining halls and canteens while, the non-compostable type includes plastics, papers, e-wastes, metal scraps, clothing, leather, etc. Fig. 3 shows the quantity of food waste being generated in the mess halls on a monthly basis. The peak observed in September coincides with the birthday celebration event hosted by the Amritapuri campus. Each and every location is provided with the required amenities for the collection of waste. The food waste collection is dependent on the dining hall timings, which is usually from 9 a.m. to 10 a.m. in the morning, 2 p.m. to 3 p.m. in the afternoon, and 9 p.m. to 10 p.m. at night.

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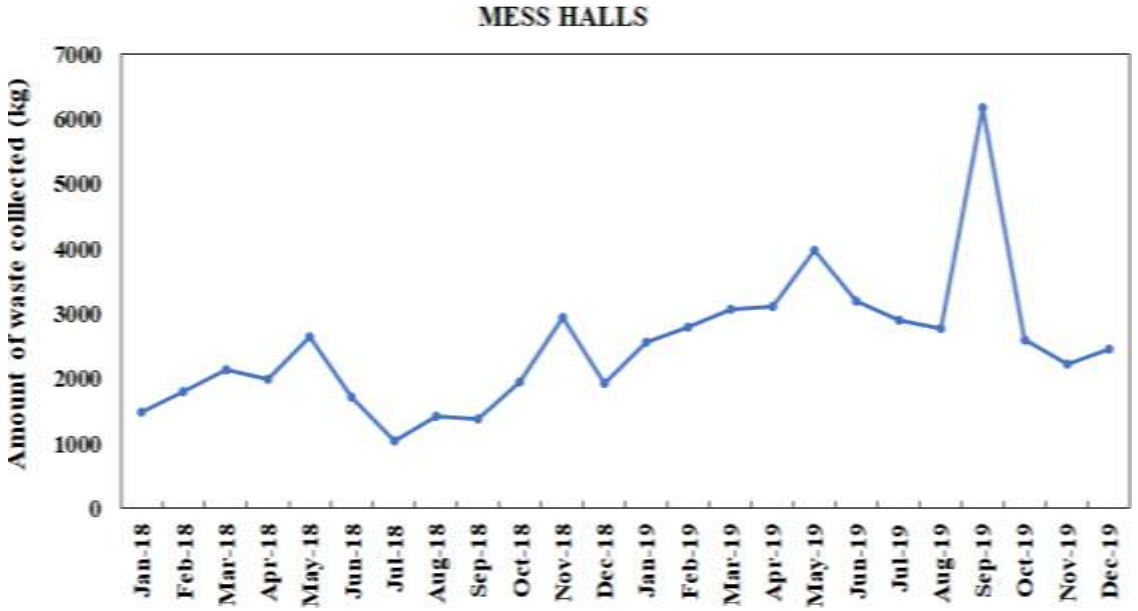

Fig. 3: Quantity of food waste collected from Mess halls

B. Sorting

Sorting plays a very important role in the waste management process in the study area. The waste is sorted into multiple categories in order to segregate reusable, recyclable, compostable and combustible material. Any waste management system will be effective only if the segregation of waste happens at the source itself. An efficient sorting of waste helps to minimize the waste that is being sent for landfilling.

Sorting is carried out in the main sorting center in two different stages: at the source and at the sorting center. At the source, separate waste bins are provided at various locations throughout the campus, to segregate the waste as organic and inorganic waste. The waste is collected from all over the campus and brought to the main sorting center for further segregation. The waste that reaches the sorting center undergoes various levels of sorting before the waste is sent for processing. At first, the waste is manually spread over a table and the recyclable as well as the reusable elements present in the waste are handpicked, by laborers with necessary personal protective equipment. The waste that remains on the table is then segregated into compostable, which is mainly food waste and wet paper, and non-compostable waste. The compostable waste is converted into bio-fertilizer using various composting techniques. The non-compostable waste is segregated into 108 categories which includes paper, plastics, cardboard, plastic bottles, textiles, leather materials, glass, metal scraps, e-waste, wood etc. Paper, card boards, plastic bottles, leather materials, glass, metal scraps and e-wastes are packed and sent to Amrita Institute of Medical Science, Kochi from where it is given to authorized dealers for recycling. The reusable materials like clothing and textiles are dry cleaned and donated to the needy people.

C. Processing and Disposal

The various methodologies followed in waste processing helps in reducing the volume and toxicity of the segregated solid wastes. The processing of wastes is closely monitored to make sure that appropriate measures are

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selected for the treatment of each type of waste materials, depending on its quantity, form, and composition. Some of these treatment methods include landfilling, thermo-chemical and bio-chemical conversion.

Recycling is the preliminary method used in the processing and disposal of solid wastes at Amritapuri. The segregation of wastes is done in such a way that, those wastes that can be used as raw materials for the manufacture of new products are separated out from the bulk. The wastes are selectively collected by the cleaning staff and are dropped off by the workers at the recycling center. However, the value of the recyclable materials is getting reduced, since the wastes are being mixed and compacted with other garbage.

Reusing and repurposing is a practice followed by the students in the campus, since necessary awareness is given to them, by conducting orientation classes in their freshmen year itself. The students reuse waste cans, bottles, tires etc. for decoration purposes during various college events. Some of the waste materials are made into curios and sold to spread awareness about the potential of repurposing waste. There are various benefits to the environment as well if these methodologies are followed, since the reuse of materials can help reduce the demand of new raw materials as well as the energy required in production of new products.

Composting techniques are widely used for the disposal of organic wastes at the campus. Composting is a biochemical conversion process, where aerobic decomposition of waste is done by bacteria, yeast, fungus and other microorganisms [10]. Various bio-composting techniques that are followed at Amrita are windrow composting, vermicomposting, and in-vessel composting.

Two Bioneer 400 systems, that use in-vessel composting of waste, are employed at the center. Each machine can handle 400 kgs of organic wastes per day. The total time required for the formation of compost is under 24 hours. Only the segregated wastes are put into the Bioneer machine. The wastes are blended with Bioculum and an appropriate absorbent. A harmless and nutrient rich compost is produced from the Bioneer unit within 24 hours. An Organic waste composter 500, that can handle 600 kgs of waste per hour, is also employed at the center. Partially composted materials from the Organic waste composter 500 are further treated in the windrow system for enhancing the nutritional value.

Vermi-composting is also widely used for the decomposition of organic wastes at Amritapuri. A well maintained vermi-compost plant is located near the campus. The vermi-wash is an excellent soil conditioner and nutrient rich organic fertilizer. All the bio-manures that are generated at Amritapuri are used as fertilizers in agricultural lands owned by the Institution in various places.

D. E-Waste

The potential e-waste generated by the student and staff community of Amritapuri Campus is effectively managed and reduced, by the conscious and determined efforts of Information & Communication Technology Services (ICTS). ICTS is the department which wholly handles the IT and Communications requirements of the entire campus and holds itself responsible for taking forward the green initiative in all its operations and decisions. Reduce, Reuse and Recycle is the mantra adopted in the University Campus, in order to deal with all the e-waste being generated.

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The e-wastes from ICTS, which were stored, are usually handed over to the government approved vendors who are responsible for the collection of such ecologically harmful materials. All working and reusable components are separated. The asset management software and records are updated accordingly. Around 4181 kgs of E-waste were handed over in the year 2018. Distribution of total e-wastes sold to authorized vendors in the year 2018 is shown in Fig.4.

Considering an annual depreciation of 30%, the average life of a computer is roughly over four years. However, with the efforts of the ICTS, the campus effectively maintains computers that are over 14 years old. Computer Systems and servers are utilized to their maximum life, by regular maintenance and servicing. Benchmarking methods guarantee that the best practices are followed, and high standards are maintained. The Periodical expansion of RAM capacity of the machines help in improving the performance of computers. The equipment that indicates poor performance are right away sent for recycling. Table 1 shows the list of items sent for recycling purposes in the year 2018. Fig. 5 gives the distribution of the various types of display monitors that were sold to the authorized vendors in the year 2018.

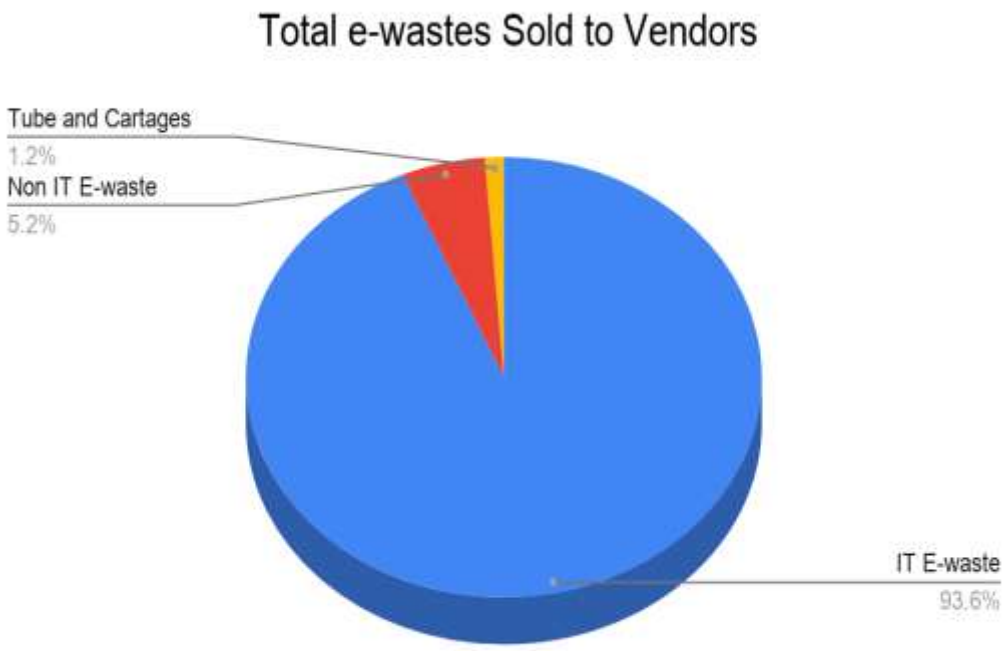

Fig. 4: Distribution of total e-wastes sold to vendors in 2018

Even though e-waste contains valuable metals like gold, silver, copper etc., it is crucial that the e-wastes are handled and disposed of properly. If the e-waste is not processed in a scientific manner, as per guidelines, it can release toxic chemicals and heavy metals, which can cause serious health hazards.

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Table 1: Quantity of E-Waste Sent for Recycling Purposes in the Year 2018

Sl No.	Items	Quantity (Nos.)
1	CPU	229
2	Display Systems	254
3	Printer	7
4	Projector	11
5	Laptop	2
6	Network Switch	14
7	Scanners	6
8	FAX	1
9	Telephone	74
10	Keyboard	95
11	Mouse	74
12	Switched-mode power supply (SMPS)	76
13	HDD	42

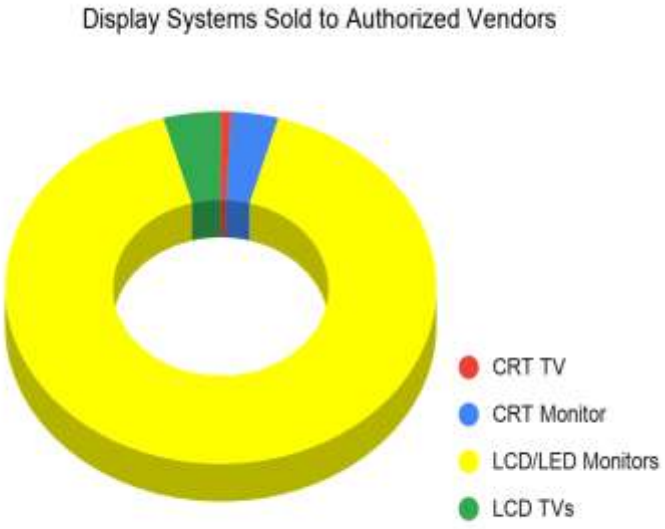

Fig. 5: Display systems sold to authorized vendors in 2018

IV. Other Waste Management Initiatives

The Amritapuri campus of Amrita Vishwa Vidyapeetham organizes the Amritavarsham event to celebrate the birthday of the Chancellor of the University, Dr. Mata Amritanandamayi Devi. Every year as part of the celebration the Amritapuri campus hosts a large number of invitees. Despite being an event with a huge number of attendees, the Amritapuri campus is kept clean and hygienic. Volunteers provide awareness and hands on training on solid

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waste management and conduct exhibitions to highlight the benefits and importance of recycling and repurposing. This task is achieved by undergoing a process of rigorous planning and execution.

A considerable amount of planning and arrangements are made before the commencement of the birthday celebrations. Initially, the venue and the premises in and around 1 km radius of the program venue is divided into multiple areas. Students and faculty of the university form teams to take up different cleanup duties. Awareness about appropriate waste management is spread among the locals and shopkeepers in these areas. The shopkeepers are provided with instruction sheets for segregating waste. The number of trash bags, required by the shopkeepers to store the waste, is then calculated and distributed. The next phase is the pre-cleanup drive, where teams of volunteers are assigned to clean the designated areas.

Amritavarsham is an event in which approximately 2000 volunteers work for over 32,000 man-hours as part of cleaning and maintaining the Amritapuri campus. Volunteers assemble at the venue and are provided with the appropriate accessories required for the venue maintenance. They are provided with green and black garbage bags to segregate the waste collected from the areas assigned to them. Each day of the celebration has an average of two cleaning sessions. Shops are also supervised from time to time to check whether the first level of segregation is happening or not. The filled garbage bags are collected from the shopkeepers and they are provided with new garbage bags. All the filled garbage bags are then loaded and transported to the sorting center. The waste is collected and transported thrice a day. Additional trips are also made for waste collection, if the waste begins to accumulate at the collection points. The green bags are transported to the composting center near the seashore while the black bags are sent for sorting and segregation.

The students and staff from the Amritapuri campus also regularly conduct clean up drives in and around Vallikavu area. Since 2007 the students and faculty actively participate in cleaning up the streets and public areas, surrounding the campus, on nationally important days like 15th of August, 26th of January, and 2nd of October. On 15th September 2018 as a part of Prime Minister's Swachh Bharat Mission, around 3000 students dedicated close to 15000 man-hours for various cleanup activities. The waste collected during the cleanup drives are transported to the main waste sorting center in the campus where it is sorted, processed and disposed of properly.

V. RECOMMENDATION

A. Automation

1) *Waste type Detection for sorting*

For proper and efficient waste management, segregation plays a major role as mentioned in the Solid Waste (Management and Handling) rules 2000 [6]. This proposed system helps in maintaining proper sanitation during sorting of the solid waste. The system consists of an Arduino Uno, Moisture sensor, Infrared sensor, Proximity sensor, dc motors, relays and three waste storage bins on a rotating platform [11]. The unsegregated waste, divided into sections, is placed on a conveyor belt which first passes through the infrared sensor to alert the Arduino on its arrival. Later it passes through the proximity sensor that emits electromagnetic waves to detect the presence of metallic objects inside the section. If metallic substances are absent, their moisture content is detected using a

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moisture sensor, which is controlled by Arduino. The detected section, if found to have a high concentration of moisture, is essentially classified as wet, and then the platform, beneath the conveyor, rotates so as to align the bin labeled "wet" in front of it, where the waste is collected. On the other hand, if the moisture content in the waste is below a threshold value, the waste will be identified as dry and the platform will rotate in the reverse direction to align the bin labeled as 'dry' in front of the conveyor. A similar process is followed for sections of waste identified with the presence of metal, using the proximity sensor. The movement of both the conveyor belt and rotation of the bins are carried out with the help of two dc motors driven by relays. This will help increase efficiency and reduce the manual labor required in the waste segregation plant.

2) Detection of the level of waste in containers

Timely emptying of solid waste from waste containers is critical for prevention of breeding of disease spreading vectors like flies and rats. Waste containers that are filled completely will eventually overflow and waste starts accumulating around the storage containers causing other problems like malodor and contamination of soil. Students, faculty, and staff who dispose of their trash will be negligent in using proper segregation techniques if bins are full and aren't emptied in a timely manner. A system should therefore be installed that detects the level of waste in storage containers and send alerts on the level of the solid waste in the containers. The system will consist of an ARM microcontroller, Wifi Module and ultrasonic sensors within the bins itself [12]. The sensor will be attached to the lid of the bin which is used to calculate the percentage of waste held within a container by finding the height of waste and subtracting the depth of the empty container to that of the current depth. The ARM can be set to send an alert using the Wifi module if the amount of trash is found to cross a certain threshold. This system can be integrated with the automatic waste segregation system mentioned in the previous section, to keep track of whether the wet, dry or metal bins are filled. With the help of this system, the employers in charge of collection and transport will be able to optimize their collection route for an efficient waste collection mechanism and decrease the chances of pest infestation.

B. Waste to Energy

The solid wastes that cannot be recycled or composted and that are completely combustible are burned in the incinerator stationed in the campus. The energy released on the combustion of the solid waste is not being recovered currently. The heat of combustion can be utilized to generate hot water, by forcing water through copper coiled tubing, that can be installed in the inner chamber of the incinerator [13]. This hot water can be supplied to the inmates of the Boy's hostel, as the incinerator is situated near the hostel.

The installed incinerator has a capacity to burn 150 kg of waste per hour. Table 2 illustrates the composition of the waste burned in the incinerator and the lower heat value of the various components in the feedstock [14].

Table 2: Composition and Energy Content of Waste

Component	Weight Fraction	Lower Heat Value (MJ/kg)
Textiles	0.55	18.3
Yard waste	0.22	6
Mixed wood	0.17	15.4
Mixed paper	0.06	15.7

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When the incinerator is run at full capacity, a complete combustion of the feedstock will generate 2241.75 MJ/hr. This energy can be used to heat water up to a temperature of 323 K. Assuming that the average temperature of inlet water is 300 K, the mass flow rate can be calculated using the following equation:

$$Q = m\,C\,(T_2 - T_1) \#(1)$$

Q - Heat energy required (J/hr)

m - Mass flow rate (Kg/hr)

T_1 - Temperature of inlet water (K)

T_2 - Temperature of outlet water (K)

Assuming the density of water is 1000 Kg/m^3, the amount of water that can be supplied to the Boy's hostel, at a temperature of 323 K, is 23.284 m^3/hr. The average daily requirement of water in the Boy's hostel is 189.65 m^3. Assuming an even distribution of water requirement throughout the day, the volume of water that needs to be supplied is approximated as 7.9 m^3/hr. Therefore, the heat recovered from the incinerator can be used to provide water at 323 K to the Boy's hostel to meet their daily water requirements.

VI. CONCLUSION

An efficient solid waste management system is critical to reducing the impact of the rising level of solid waste on the environment. Improper processing and disposal of waste is causing contamination of surface water as well as groundwater resources. The leachate from the water dumped in landfills, without the necessary processing, sometimes contains toxic heavy metals, which in turn can cause serious health hazards to communities living nearby. Malodor and spreading of diseases by breeding vectors like flies and rodents are other major problems that are putting pressure on the urban local bodies. If every institution that generates waste can emulate some of the practices followed by Amrita Vishwa Vidyapeetham, the burden on the urban local bodies can be reduced and they can focus on managing and handling the waste generated by the section of the society that needs assistance for proper processing and disposal of their solid waste.

A systematic and organized sorting of waste like that established in Amritapuri campus, can help to segregate the waste in such a way that maximum resources can be recovered from it. Effective recycling can be done only if the waste is segregated at the source itself. This in turn can help to reduce the stress on the environment as the more plastic is recycled, the less of it gets dumped in landfills.

Adequate importance has to be given in the handling and disposal of e-waste. A good amount of precious metals can be recovered from e-waste. However, if the e-waste is not handled properly, as per the guidelines, it can also cause severe health hazards. Some of the e-waste even contain toxic and radioactive materials, and it should be ideally sold to authorized vendors who have the necessary expertise to process and dispose e-waste.

During the floods that occurred in Kerala, in the recent past, many of the drinking water sources were contaminated, since solid wastes were carried along with and deposited by the floodwaters in groundwater wells and other drinking water sources. Proper management of the solid wastes therefore plays a vital role not only in

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preventing soil pollution but also water and air pollution as well. Recent advances in technology have changed the perception of solid waste from that of a burden to that of a resource, however this requires all the various stages in solid waste management and handling to take place effectively.

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