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Scenario of Solid Waste Management in an Institutional Campus – A Case Study

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Abstract- Solid waste management is multi disciplinary field embracing waste collection, transfer, haulage, and disposal and its impact is wide. It is therefore important to take a broad view and not to consider disposal options within the narrow confines of a particular technology. The solid waste generated in the campus is about 1.4 tons per week which includes mainly paper wastes, food wastes, garden wastes etc. The generated wastes are collected in the plastic drums kept in each and every part of the buildings. The wastes from each and every building were weighed before the segregation process. Dry leaves and twigs constitute maximum quantity with 35% of total weight & Food waste constitutes about 30% of total weight. Since the compostable matter was found to be higher, Vermicomposting was used as the disposal technique. Vermicomposting is a green technology that converts organic wastes into plant available nutrient rich organic fertilizer. It has also found to reduce heavy metal concentration in contaminated feeding materials. The earthworms used for the study is "Eudrillus eugeniae" also known as African Night crawlers. The Vermicompost was analyzed for available phosphorus, available potassium and total nitrogen. The results of the pilot scale tests enable improvement to be made to the full scale vermicomposting bin design. This can enable full scale implementation of waste reduction initiative in a PPP model as part of the sustainable campus initiatives [23].

Keywords: Disposal, Segregation, Institution, Nutrient, Vermicompost.

I. INTRODUCTION

Solid waste generation is a continually growing problem at global, regional and local levels. Solid wastes are those organic and inorganic waste materials produced by various activities of the society, which have lost their value to the first user. Improper disposal of solid wastes pollutes all the vital components of the living environment at all levels.

The waste generated in the campus is not being managed properly and no attention has been given in the process. This necessitates management of solid waste at generation, storage, collection, transfer and transport, processing, and disposal stages in an environmentally sound manner in accordance with the best principles of public health, economics, engineering, conservation, aesthetics and environmental considerations. Thus, solid waste management includes all administrative, financial, legal, planning, and engineering functions.

An effort is made to study the solid waste management practice as a pilot study in the JSS technical institution campus whose waste generation resembles a typical urban community, equivalent to a ward under City Corporation's jurisdiction. The proposed strategies can be replicated in large communities and townships. The following work gives a first survey about the challenge to get data about quantity and quality of MSW and about their management in gated communities with the example of the campus of JSS technical institution.

II. REVIEW OF LITERATURE

Literature pertaining to the present study, namely vermicomposting of the solid waste in the institutions, has been compiled from various sources such as institution library, web browsing related to vermicomposting & waste management in general. However, only most relevant literature has been cited.

Sebastian Meier et al (2011), has has made a study on Waste Management System in gated communities with an example of The Vellore Institute of Technology (VIT) University campus, Tamil Nadu. The waste is collected from the whole campus and carried to the segregation plant, where the waste is separated into different fractions (recyclable sellable waste, non-recyclable waste, biodegradable waste). As the composition and material flows of the municipal solid waste could be determined, unfortunately construction waste, bulky waste and other waste were not quantifiable. The evaluation of the amount of each fraction was difficult too, because of lack of data. From the interviews conducted, literature study, monitoring, analysis and assumptions the biodegradable waste of 85% and the rest of 15 % was found to be recyclable and non-recyclable.

On basis of the current available data, variants were modelled by Life Cycle Inventory analysis software named Umberto®. Variant A shows the material flows by using the existing biogas and composting plant and producing fertilizer. The variant B is an assumption by using all the biodegradable biomass to treat it in biogas and composting plant and using the fertilizer in the VIT-Campus. In variant A (0.03 m^3/h) and variant B (56 m^3/h)

biogas is produced, which could be used for lighting or cooking processes (for heating water). Even in variant B the biogas production is not efficient for using a CHP-plant.

Potential for optimization are in operation and maintenance. Furthermore structural measures could decrease the impact on the environment and to health of the workers (concrete ground plate, temporary waste storage). For dimensioning a bigger biogas plant, it is necessary to have a correct balance of organic waste, which could be used for biogas production. These plants would be efficient only when the people who are using and operating it are well educated and well trained. In general the concept of the waste management for collection and transporting in VIT Campus is working fair and no waste is lying or dumped in the campus side, because every day gardening people /scavenger cleaning the campus very well.

Nalawade et al, (2009) have made the study on integrated use of tannery wastewater, municipal solid waste and fly ash amended compost on vegetable growth.. The raw materials were mixed in the ratio 2:2:1. In addition the tannery waste water is spread on this mixture every day for maintaining the moisture level. The 2 x 3 feet wooden boxes are made for the composting. Equal amount of bedding material is added in these boxes, earthworm species Eisenia foetida is inoculated in one box and in other box Azotobactor species is inoculated as bacterial culture. The third box is used as pit for composting. The bedding material is kept for 45 days for compost making. At the interval of 15 days the compost were analyzed for their NPK content. After completion of the process, the compost is amended with fresh fly ash generated in coal based thermal power plant were used, for evaluation of impacts Pisum sativum and Trigonella fenugrecum plants were used. The soils in which these plants are planted were analyzed for different physico-chemical parameters.

During the analysis of the soil and bedding material the following results were obtained. The results show the pH value of soil and bedding material varies between 6.8 ±0.29 and 7.5 ± 0.32 respectively. The soil contains significant amount of organic carbon (1.48 ±0.04), Nitrogen (0.01 ±0.004), Phosphorous (1.61 ± 0.06), Potassium (1.81 ± 0.05), Calcium (0.74 ± 0.03) and Magnesium (0.1 ± 0.03) respectively. The bedding material is partially degraded for about 8 days. The soil taken for the potting is from the garden. The pH value of the soil is slight alkaline. The fly ash collected from coal based thermal power plants was used for compost amendment. In Pisum sativaum chlorophyll a in control pot is 48.9 mg/100 mg. chlorophyll-b is 50.75 mg/100mg and total chlorophyll is 99.65 mg/100mg, while polyphenol is reported as 572 mg/100 mg. Pisum sativaum is potted in all three types of composts as well as in soil as in control pot. In Pisum sativaum, pit compost pot having total chlorophyll is 100.96 mg/100mg, Vermicompost pot having 100.55 mg/100mg and bacterial compost pot having total chlorophyll is 98.38 mg/100mg while Polyphenol in these 3 pots is 580 mg/100mg, 577 mg/100mg and 593 mg/100mg respectively. In case of Trigonella fenugrecum control pot having chlorophyll a 50.24 mg/100mg, chlorophyll b is 45.83 mg/100mg, while total chlorophyll is 96.07 mg/100mg. Polyphenol is 525 mg/100mg, vermicomposting pot having chlorophyll a 53.75 mg/100mg, chlorophyll b is 49.03 mg/100mg, total chlorophyll is 102.78 mg/100mg. while Polyphenol is 521 mg/100mg. bacterial composting pot is having chlorophyll a 50.30 mg/100mg, 45.88 mg/100mg and total chlorophyll is 96.18 mg/100mg and polyphenol is 524 mg/100mg. Chlorophyll and Polyphenol content in both the species of plants is in the range of control plants.

Ramachandra et al, (2007) conducted an Environmental audit of Municipal Solid Waste Management in Bangalore city, the audit has brought out the key issues that need immediate attention and minor lacunae that pose major hindrances in the further process of the system. In the storage function, only 49% of the present bins are covered. In collection, 17.5% of the commercial areas have community bins and 94% of the residential areas have adopted the door-to-door method. With these methods of collection, only 3% of waste segregation has been achieved. There are no transfer stations present and out of the trucks present, only 41.43% have polythene covering. Recycling is carried out mainly by the informal sector achieving a high level of efficiency. 3.14% of waste reduction is achieved through composting and 60.71% of the waste is disposed in dump yards and 21.14% is disposed in open quarry sites.

Waste disposal needs immediate attention and strict monitoring. The setting up of sanitary landfill sites has to speed-up and this needs to be given top priority. The number of treatment process plants has to be increased to manage total quantity of waste generated. Many new techniques have been implemented for storage, collection, transfer and transportation. These techniques have brought about many positive changes and have increased the efficiency of the MSWM system. However, segregation of waste at each step is not being carried out. The segregation of waste during storage, collection and transportation has to be set in place for the efficient running of the process plants. Proper training and education needs to be provided to the workers and public awareness programs should be conducted regularly. The occupational and health and safety measures taken by the authorities are not sufficient. Health and safety programs have to be conducted regularly to check the health condition of the workers in the various areas of MSWM and they should be educated on the health hazards related to their work and the importance of wearing the safety gear.

Chanakya et al, (2008) made a study on a sustainable waste management system for Bangalore. The study says that the existing solid waste system in Bangalore city is effective in carrying out the functions of primary collection and transport. However, there has been a significant problem in realizing the large sustainability goals due to the systems heavily relying on centralized waste treatment and disposal system. In fact the current payment mode is conducive to showing at least 30% land filling fraction in the USW collected. This is not conducive to sustainability as there is no reward for complete recovery of recyclables and fermentables. On the other hand, with some modifications in the way waste is collected, it is possible to run decentralized, ward-wise or smaller systems that are more sustainable (economically, environmentally and socially), and overcome some of the lacunae faced in the centralized systems. Decentralized systems of the future can provide greater sustainability but will require a higher level of waste generation and handling discipline.

Ramachandra et al, (2003) worked on Exploring Possibilities of Achieving Sustainability in Solid Waste Management with an example of Bangalore city. The study reveals that Developments in the waste management systems in Bangalore is slow paced nevertheless a sincere one; however it needs up gradation in the areas of processing and disposal. Political and financial hurdles and lack of cooperation by the public in general has created bottlenecks in improving its efficiency. The potential of community participation, human resource development, and legal mandates has to be realized and subsequent changes brought about. Adoption of latest technologies such as MIS-GPS, GIS system has to be taken into consideration while developing a waste management system for Bangalore. The study on IISc campus can be used as a model for the wards in Bangalore. However for any waste management to be successful, the government should step up and take the required initiatives. Even though financial constraints are a part of the system, the government can make a formal and sincere commitment for an integrated SWM approach, fully recognizing the advantages of the existing informal recycling network. Waste recycling can be promoted through consumer campaigns that will encourage citizens to cooperate in waste separation and to purchase recycled products. Also, waste authorities should encourage composting and bio gasification of wastes, which will reduce the volume of waste to be disposed of. Finally, no SWM can be effective without proper monitoring of its disposal activities. Therefore its effectiveness should be tested on a regular basis.

Gurav et al, (2011) studied on the Production of Vermicompost from Temple Waste (Nirmalya) in Maharashtra. In the present studies the well known species of earthworm used was Eudrilus eugeniae. After biomethanation of temple waste, slurry was mixed with admixture of temple waste solids (remaining leaves and flowers after extraction of their fluid part for preparation of microbiological media) and cattle dung (cattle dung: solids) in 50:50 proportion. This admixture was mixed with biogas digester effluent in equal proportion and was kept for partial decomposition in the trays for 30 days and then this material was used for vermicomposting. For vermicomposting plastic tubs of size 25 X 15 cm and of 2 kg capacity were used. The 2 kg material was filled in the set of six plastic tubs (in triplicate) and kept in dark for five weeks by adding two earthworms / pot. Every week the weight of earthworm biomass / pot and count of cocoons / pot was taken after thorough washing and blotting of earthworms and cocoons and then they were re-inoculated in the respective pots. This procedure was followed for every week.

The temperature range selected for experiment was 15, 20, 25, 30, 35 and 40Oc taking into account average minimum and maximum temperatures found in the Sangli area and in the seasonal variations in the year. For every temperature selected, the three plastic tubs / pots were used and were incubated for five weeks in BOD incubators. The PH of vermicomposting material was adjusted with 1 N HCL / 1 N NaOH to 2, 3,4,5,6,7,8,9 and 10. The pH of the material was finally adjusted to 7.0 and the particle size was fixed as 1-2mm. The moisture contents of vermicomposting material were adjusted to 50,60,70,80 and 90 % with water. Using Optimized parameter of vermicomposting i.e. temperature of incubation (25 particle size (1 - 2mm) and moisture content (80%) of organic material vermicomposting was done in 2 kg pots (in triplicate) and after 5 weeks of incubation the vermicomposting was separated by straining out off juveniles (earthworms) and their cocoons and then it was analyzed for the percentage of N, P and K and used for pot culture studies.

For pot culture studies plastic pots with 5 kg of garden soil were used for pot culture trial studies. Different common flowering plants were selected and used to study the effect of Vermicompost on enhancement of plant growth. The experiment was performed for period of three months. In the studies two sets of flowering plants in the pots were prepared - a control set with only soil and test set with 10% Vermicompost added with soil in the pots. Daily 0.5 L of tap water was added each pot. The extent of plant growth (height of plant in cm and no. of flowers), flowering time and number of flowers were studied every week for three months. Extent of enhancement in plant growth and flowering by using Vermicompost was studied.

The temple waste based biogas digester slurry admixed with cattle dung and temple waste solids after partial decomposition works as an excellent raw material for vermicomposting using Eudrilus eugeniae earth worm which can produce Vermicompost with good fertilizer value and which can be used for plantation in the temple premises. This eco-friendly method of temple waste management should be extended for all the temple and similar wastes.

Bachman et al, (2007) studied on the growth of bedding plants in commercial potting substrate amended with Vermicompost. Vermicompost of pig manure origin was added to a commercial potting substrate. Media components were mixed for three minutes in a rotary mixer to ensure complete dispersal of the material components of each mix ratio. Seeds of 'Rutgers' tomato, 'Queen Sophia' French marigold, 'California Wonder' bell pepper and 'Imperial' cornflower were sown into 200 cell (33.3 mm • 44.45 mm) plug trays containing one of the three VC mixes at a rate of one seed per cell. The plug trays were placed in a greenhouse under high humidity and mist until emergence. Seeds were considered emerged when the cotyledons came through the surface of the potting substrate, typically after three days for tomato and marigold and seven days for pepper and cornflower. At that time, the percent seedling emergence was determined. Beginning seven days after emergence, five seedlings of each species were sampled from each media mix treatment for determination of leaf area, and the dry weights of shoots and roots daily for 12 consecutive days. Fourteen days after emergence seedlings of tomato, marigold, pepper, and cornflower were transplanted into large cell six-packs having cell dimensions of 5.7 cm • 5.7 cm • 8.25 cm in a factorial design containing 0%, 10%, or 20% VC: MM360 mixes. There were two fertilization treatments. One group received no supplemental fertilization and was irrigated with clear water and the other group received supplemental fertilization from Peter's Peat-Lite Special 20-10-20 (20N-4.4P-16.6K) (The Scotts Company, Marysville, OH) at the concentration of 200 mg N L_1 twice weekly with clear water used for the intervening irrigations. The transplanted plugs were grown for 28 days and harvested. There were six replications and treatments were arranged in a complete randomized design within each species of plant.

Temperature in the greenhouse was controlled using a computer control system with a set-point of 23 _C and a range of 23–30 _C. Data collected for each species included shoot and root fresh weights, shoot and root dry weights, and leaf areas. Analysis of plant growth data included analysis of variance, orthogonal contrasts, mean separation using Fisher's LSD (P = 0.05), and regression analysis.

The addition of Vermicompost in media mixes of 10% VC and 20% VC had positive effects on plant growth. The greatest growth enhancement was on seedlings during the plug stage of the bedding plant crop cycle. Growth increases up to 40% were observed in dry shoot tissue and leaf area of marigold, tomato, green pepper, and cornflower. The increased vigor exhibited was also maintained when the seedling plugs were transplanted into larger containers with standard commercial potting substrates without Vermicompost. Additionally, there were benefits apparently resulting from the nutritional content of the Vermicompost. All of the plugs were produced without the input of additional fertilization. The potential exists for growers to use Vermicompost-amended commercial potting substrates during the plug production stage without the use of additional fertilizer.

Jaya Nair et al, (2006) made studies on the Effect of pre-composting on vermicomposting of kitchen waste. The wastes used in this experiment were grass clippings, shredded paper (newspaper and some office paper) and kitchen wastes (Lettuce, cabbage, oranges, tomatoes, mandarins, pears, apples and broccoli). These ingredients were selected based on their availability and production in an institution. Grass clippings and shredded paper was used as bulking materials and a source of carbon. Thermo composting was conducted in tumbler composting bins and vermicomposting in Styrofoam boxes. Worm boxes were initially set up using vermicast collected from an established worm farm to a depth of 10–15 cm to start the process. Approximately 200 g of composting worms were added to each box comprising of a mixed species of 40:60 ratio of Red (L. rubellus) and Tiger (E. fetida). The tumbler bins were tested daily to note the temperature, pH, and moisture content. On days 6, 9, 12, and 15, 2 liters of partly composted waste was fed to separate worm farms for the completion of process. Vermicast from worm boxes were analyzed for its physical and chemical quality at the end of 21 days. Microbial quality of compost was assessed based on the presence of E. coli, E. faecalis, and Salmonella spp. Microbial analyses were conducted at the end of 21 days composting and later monthly until the composts were found safe for handling. The kitchen waste was not expected to contain pathogens, however the lawn clippings may contain pathogens from pet feces and other sources and therefore microbial analyses was considered essential to assess the safety of the product.

The samples were tested for pH, moisture, compaction rate, and carbon: nitrogen ratio. The temperature was measured at inside the tumbler and air temperature outside the tumbler. Total carbon was tested using high temperature non-dispersive infrared gas analyzer and total nitrogen from which carbon: nitrogen ratio (C: N) was calculated. For the microbial analysis, 1 g of compost was weighed out and added to 9ml of distilled water, shaken vigorously and then mixed with a rotating mixer on high speed for 10min. One ml of the mixture was then added to 10ml of distilled water and again mixed in the same manner. The samples were analyzed for the concentration of E. coli and E. faecalis using the most probable number (MPN) method respectively. All tests were carried out in duplicates. For E. faecalis and S. typhimurium the initial dilution was made to 1:100.

The study concludes that Thermo composting prior to vermicomposting was helpful in waste stabilization, pH and moisture stabilization as well as for mass reduction. Vermicomposting after thermo composting was effective in inactivating the pathogens. This study revealed that while treating kitchen waste, thermo-composting for 9 days followed by 2.5 months of vermicomposting produced pathogen safe compost.

Ndegwa et al, (2001) carried the studies on integrating composting and vermicomposting in the treatment and bioconversion of bio solids. The integrated approach suggested in this study borrows pertinent attributes from each of these two processes and combines them to enhance the overall process and improve the products qualities. Two approaches investigated in this study are: (1) pre-composting followed by vermicomposting, and (2) pre-vermicomposting followed by composting. The substrate was bio solids (activated sewage sludge) with mixed paper-mulch as the carbon base. Eisenia fetida (red wigglers) was the species of earthworms used in the vermicomposting processes. The results indicate that, a system that combines the two processes not only shortens stabilization time, but also improves the products quality. Combining the two systems resulted in a product that was more stable and consistent (homogenous), had less potential impact on the environment and for compost-vermicomposting (CV) system, the product met the pathogen reduction requirements.

From the waste-treatment point of view, the results suggest that, the combined systems are better treatment options than the vermicomposting system by itself because they resulted in higher reductions of both TS and VS. TS were reduced by approximately 45% in both systems, representing a significant reduction in both the handling and transport costs of the product. The higher reductions in VS suggest that more stable products were obtained from these two integrated systems. Large reductions in soluble N and a significant reduction in soluble P were also observed in all the products. Although the reduction in soluble N was not significantly different among the three systems, the reduction in soluble P was significant. The VC-system displayed the greatest reduction. This means that, the impact of P on the environment was more mitigated in the VC-system than in the other systems. The composting-phase in the combined systems was primarily intended to provide the temperature required for pathogen kill to meet the EPAs PFRP requirement for compost. This requirement was met in the CV-system but not in the VC-system. The product coming from the VC-system does not automatically meet the EPAs PFRP temperature criterion and therefore would need to undergo further testing prior to general distribution. The particle size analysis showed substantial reductions in size in all the systems but more reduction was observed in the combined system. The CV-system was the finest and most homogenous.

The product from the CV-system seems to be better in many ways. It was adequately stable, had less soluble N and P, met the EPAs PFRP criterion, and was the most homogenous. Moreover, by regulating the MC content of the feedstock, it would be possible to achieve the required composting within a shorter time, thus effectively reducing the overall processing time for the entire CV-system.

Cristina Lazcano et al, (2008) studied the Comparison of the effectiveness of composting and vermicomposting for the biological stabilization of cattle manure. The aim of this study was to evaluate the effectiveness of the active phases of composting, vermicomposting, and also a combination of composting and vermicomposting for reducing the polluting potential and for stabilizing cattle manure in the short-term. For this, the degree of decomposition as well as the microbial activity and microbial composition of the resulting products after the active phase of composting and vermicomposting were analyzed. None of the treatments significantly reduced the dissolved organic carbon and dissolved organic nitrogen contents relative to the control, and therefore more time may be required for stabilization. Nevertheless, the lowest values of microbial biomass and activity corresponded to the earthworm-worked substrates, in which fungal growth was also promoted; the combined treatment (composting + vermicomposting) was the most effective in terms of stabilizing the cattle manure. Moreover, earthworms promoted the retention of nitrogen and gradual release of P, as well as a reduction in electrical conductivity, thereby producing improved substrates for agricultural use.

The treatments considered here (active phase of composting, vermicomposting and composting with subsequent vermicomposting) exhibited important differences in efficiency in terms of the short-term stabilization of cattle manure. Although the reduction of easily metabolizable compounds was not sufficient for complete stabilization in any of the treatments and longer processing times appear to be necessary, there were clear differences in the microbial composition – and consequently the degrading metabolism of the different substrates. While the cattle manure subjected to the active phase of composting did not differ significantly from the control, both Vermicompost exhibited lower levels of actinomycetes, enhanced fungal growth and had low concentrations of total microbial biomass. In addition, earthworms appeared to modify the degrading activity of the manure to a much greater extent than the active phase of composting. This was reflected by the lower EC, C to N ratio and pH, as well as by a more gradual release of P, which made the Vermicompost more suitable substrates for agronomic purposes.

Giresh Mohan et al, (2016) made a case study in which ITC Limited, in collaboration with Muskan Jyoti Samiti, an NGO, and the local municipal authority, initiated a pilot PPP project on solid waste management in the year 2006. With persistent focus on processing, recycling and user fee, this initiative has been able to surpass the national benchmark of 80% waste recovery set by the Ministry of Urban Development (MoUD). The cost of collection and processing is covered through revenue from user fees and compost sale.

Saharanpur city situated in north-west Uttar Pradesh with nearly 129,000 households, generatesabout307 MT of waste per day. As per the 2011 census, the population of the city has grown 2.7 times the growth of the district population. This is primarily because of very high migration from nearby rural areas due to limited and uncertain agriculture-based livelihood opportunities. With such a high influx of the population to the city, demand for civic amenities started growing manifold. SWM practice followed in Saharanpur city is no different from other cities of India. Segregation and storage at source was lacking and the decomposable and non-decomposable wastes are disposed of at common communal bins. Later, waste from these bins is transported to landfill sites for dumping by Municipal Corporation. Due to poor knowledge, insufficient number of bins and apathy towards this cause, households often tip their waste on vacant lands and/or streets. Due to limited number of waste workers, it was difficult for the SMC to pick up waste from the streets.

Private waste collectors also collect waste from households in a few localities. However, they are interested only in dry recyclable waste, which they sell to earn revenue, leaving organic and non-recyclable material in neighbouring street corners, vacant plots and community bins. Thus, overflowing garbage bins, foul smells emanating from dumps and unprocessed waste at landfills caused several environmental risks. More than the willingness of SMC, the absence of an alternate model was perhaps a major deterrent in tackling this issue. ITC, in collaboration with the local municipality, the district administration and a partner NGO, Muskan Jyoti Samiti (MJS), initiated a pilot Public Private Partnership (PPP) project on solid waste management in Saharanpur city in the year 2006. The objective of this PPP was to develop a replicable and financially viable model to manage waste and reduce the quantity of solid waste disposed in landfills. Integral to the project was also the objective of providing a decent and sustainable source of livelihood to waste collectors and rag pickers.

Against the general practice followed by ULBs of collecting waste from community bins, this model emphasised on door-to-door collection of waste for 6 days in a week. Each waste collector, equipped with hand pulled carts, with two separate bags for recyclable and non-recyclable waste, provides daily services to around 250 households. This process is overseen by a supervisor who looks after 1,000-1,200 households. Primary segregation is attempted at the household and collection levels in this model. Households are made aware of the importance of primary segregation through various media such as daily reminders, road shows, pamphlets, posters and street theatre. The model works as a decentralized waste management system. Waste collected from households is transported by waste collectors for secondary segregation to the waste management sites located within city in the land provided by the SMC. Rag pickers are involved in segregation at these waste management units. Biodegradable waste is separated from the waste and is processed to make compost. Non-biodegradable recyclable waste is sold to private vendors and the remaining non-recyclable waste goes to landfills.

Since this initiative had introduced a different way of waste-handling in 2006, it took some time to overcome initial inhibitions and win the confidence of the community and other stakeholders. Starting with a few families in a locality in 2006-07, the model currently covers over 18,000 households spread over 30 wards of the city.

On an average, the recovery of biodegradable material in the total waste is around 60% for the 9 year period in this model, followed by recyclable waste. Over the years 2012-13 to 2014-15, there has been steady increase in the recovery of biodegradable waste due to focused campaigns on segregation and recycling of waste at household level as well as improvement in waste processing. The non-recyclable waste, which goes to landfills, was confined to little over 10% in 2014-15, which was considerably low compared to many other successful model in cities like Pune, Ahmedabad etc.

90% recovery of waste under this initiative is not only notably high compared to the average performance of ULBs (31.73%), but also exceeds the desired national benchmark of 80%. It is therefore important to note that the model adequately fulfilled one of its objectives: compared to the practice of dumping everything in landfills as is done in the traditional ULBs model, which causes immense environmental and public health hazards, most of the waste in this model is decomposed and recycled. The organic material present in municipal waste is converted into compost by aerobic decomposition using open aerobic brick structures. Samples from each lot of the compost are tested in the labs of institutions like the National Botanical Research Institute, Lucknow, to know the nutrient levels before marketing. Currently, over 350 MT of compost is produced and sold annually.

User charges, sale of recyclable waste and compost are the major sources of revenue in this model. Recyclable waste is sold to local vendors and compost produced is sold to the bulk buyers and nurseries within and outside the district at Rs 4-7 per Kg. This model firmly focuses on the “polluters pay” principle and thus households are charged with Rs 20-30 as monthly service fee. Out of the total revenue generated in the last 3 years, the highest (around 48%) comes from user charges, which is a positive indicator for the sustainability of the model as it displays the community's willingness to pay for provision of quality and reliable services. Compared to an average 31.4% user charges collection in other ULBs, the average in last 3 years in this model has been 91.5%, which is also higher than the desired benchmark of 90%. Increasing trend of non payers is due to expansion to new areas, which gradually goes down with time.

The model has not become fully self-sustainable so far. One reason for this lies in enhanced outlays to fund major expansion of the project since 2012-13, which increased costs and lowered revenues. However, the costs of collection and processing are covered entirely by the revenue generated. The average cost recovery has been around 70%, which though less than the desired service level benchmark of 100%, is significantly high compared to the average performance of many other ULBs. The gap between cost and revenue is currently being funded by ITC. Nevertheless, there is a potential to enhance revenue further through tertiary segregation of the waste, especially of recyclable parts and increasing the services charges.

III. MATERIALS AND METHODS

Description of the study area: The JSS technical institutions campus is located adjacent to Manasagangothri, the campus of the University of Mysore with an area of about 120 acres (0.5km^2) with Longitude - 76° 42' E; Latitude 12° 18' N. By and large floating population inside the campus is around 6000.

Everyday a definite amount of solid waste is generated from different parts inside the campus. The waste is mainly generated from canteens, hostels, offices, labs, cafeteria, and also the leaves falling from the trees and plants. The waste generated in this campus includes plastic, paper, glass, cloth, organic waste etc. Table I shows the different types of wastes generated in different parts inside the campus.

TABLE I: Types of Waste Generated inside the Campus

Source	Type of Waste Generated					
	Food waste	Paper & Cardboard	Glass	Plastics	Cloths	Leaves & Twigs	Metals & Rubber
Hostel (Boys)		✓	✓	✓	✓	✓	✓
Hostel (girls)	✓	✓	✓	✓	✓	✓	✓
Canteens	✓	✓	-	✓	-	-	-
Offices	-	✓	-	✓	-	-	✓
Banks	-	✓	-	✓	-	-	✓
Cafeteria	✓	✓	-	-	-	-	-
Miscellaneous	-	✓	✓	✓	-	✓	-

Segregation of Waste: While collecting the waste from each of the buildings, the organic waste and inorganic waste were segregated and stored in different containers. The organic waste is further segregated at the processing yard to use only biodegradable materials in the compost pits. The non biodegradable wastes are further segregated for recycle and reuse. Fig 1 and Fig 2 shows the segregation of dry and wet wastes respectively. In canteens and other hostel messes also the wet and dry wastes are collected in separate drums. In other places like banks and offices, only one waste collecting bin are used since, wet waste generated is very much negligible.

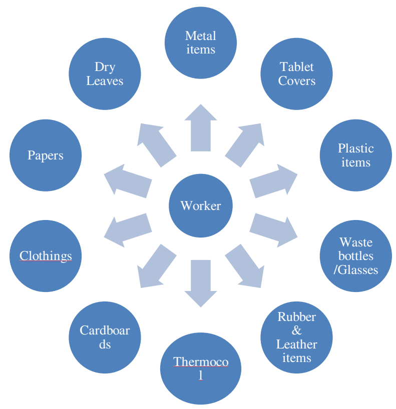

Fig.1. Segregation of Dry Wastes.

Fig.2. Segregation of Wet Wastes

Transportation of Wastes: The waste collected in auto tippers from every part of the campus is transported to the secondary containers. The secondary containers containing the biodegradable waste is transported to the compost facility and the non biodegradable waste is further segregated for recycle and reuse. The waste collecting vehicle arrives to the campus everyday by evening and collection of waste starts from boy's hostel and the vehicle travels throughout the campus and collects waste from each and every part of the campus and final point of collection is at the main canteen of the campus. After the collection process the vehicle transports the wastes to the landfill site located at the outskirts of the city.

Physical Characteristics of the Solid Waste: The characterization of solid waste as physical components is to incorporate those items that are readily identifiable. This includes the determination of percent contents of various ingredients of the solid waste. 20kg of sample is used for the physical characterization. The samples collected are sorted out physically, into various ingredients such as paper, glass, plastic etc. on the sorting platform. The individual components are separated and weighed. The physical analysis is based on the wet weight basis, which helps in the housing system of frequent collection and disposal. The physical characteristics are important to know the percentage of recyclable material, compostable material and inert material in the waste.

Chemical Characteristics of the Solid Waste: Information on the chemical composition of solid wastes is important in evaluating alternative processing and recovery options. A sample of 20kg used for physical analysis is reduced to 5 kg by using the method of quartering. In this method, the mass is divided into four parts and two diagonally possible opposite parts are taken and mixed, while other two are discarded. The sample is again mixed and same procedure is repeated. Finally the outer four diagonals are taken for analysis.

The sample of 5 kg is dried and grounded till it passes through a sieve having a pore size of 0.45mm. The analysis was carried out for various parameters like pH, moisture content, nitrogen, potassium, phosphorus, organic matter, carbon content, and C: N ratio. The procedure followed is as per IS: 10158-1982 and IS: 9234-1979.

Vermicomposting: Vermicomposting is a simple method involving the stabilization of organic solid waste through earthworm consumption which converts the waste material into worm castings.

Two compost pits were constructed using cement bricks with dimensions of 5ftX2.5ftX2ft. Earth was excavated up to 1.5ft and the pit was constructed from below the ground. Based on previous studies, the dimensions of the compost pits were fixed depending upon the quantity of waste generated. The pits were constructed in the back side of boy's hostel as it is an isolated place and there will be no odor or other problems. Plate 2 shows the pits constructed for vermicomposting.

Plate.1. Pits constructed for Vermicomposting.

After the collection of wastes, the compostable matters like fruit and vegetable peelings, unused food materials are separated. The pits were cleaned and all the unwanted plants and weeds were removed with the help of a worker. To the cleaned pits, water is sprayed. After few minutes Cow dung slurry was sprayed all over the pit, this is done to accelerate the process of composting. After that the fruit and vegetable peels and other compostable matter are added.

Next step is the addition of Earthworms in the ratio 10:1 (1kg of worms to 10kg of wastes). After the addition of worms, dry leaves and twigs were added on top of it, and then it was allowed for 60 days for the completion of the composting process. Once in 3 days food wastes are added as feed for the worms.

Plate.2. Eudrillus Eugeniae Species of Earthworms used in the study.

Finally, after the compost is ready it was taken out for sieving to get Vermicompost materials. Everyday water was sprayed to maintain the moisture content required for the survival of the worms. The earthworms used for the study is Eudrillus eugeniae, also known as African Night crawlers. Plate 3 shows the earthworms used for the study. The Vermicompost was analyzed for various parameters as per the Standard procedures. The Parameters analyzed are available phosphorus, available potassium, and Total nitrogen. Available phosphorus was estimated calorimetrically after acid digestion. Potassium was obtained by flame photometry method and total nitrogen was obtained by Kjeldhal method.

IV. RESULTS AND DISCUSSION

Present Scenario of Waste Management in the Campus: At present the solid waste management inside the campus is very poor. The generated wastes are collected in the plastic drums kept in each and every part of the buildings. Presently, about 170 waste collecting drums are kept in different parts of the campus for the collection of waste. Drums are kept in hostels and canteens for the collection of wet waste and dry waste separately. In hostels all the food wastes are collected in the plastic drums and other wastes are collected in separate drum. In canteens and cafeterias the plastic and paper cups and plates are collected in the bins meant for it. The paper and other wastes from the offices and banks are collected in the separate bins.

The wastes which are dumped in the bins are later transferred to the waste transport vehicle (auto) and it is further transported to the solid waste dumping yard which is located at the outskirts of the Mysore city. No segregation is done in the campus, only at the time of transferring to the auto, wet and dry wastes are collected in separate plastic covers. The waste transporting auto collects the wastes from each building inside the campus everyday by evening. The dry leaves and twigs which are generated are swept by the sweepers and are collected in the plastic drums. The collected leaves and twigs are burned inside the campus in a remote place where no other activities are carried out.

Quantification of the wastes: The solid waste generated was weighed using a weighing balance. The wastes from each and every building were weighed before the segregation process. This process of weighing was done for 7 days i.e., from Sunday to Saturday. This was done to get the correct weight of wastes generated in the campus everyday in a week. The results obtained are tabulated and is shown in the Table II below.

From the above data, it can be seen that the total quantity of solid waste generated in one week is 1377.19kgs or 1.37719 tonnes.

Table II: Quantity of Waste Generated inside the Campus from various Sources.

Sources of waste in the campus	Quantity of Wastes generated everyday in a week in kgs						
	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Hostel (Boys)	43.45	47.18	45.61	44.80	44.12	47.59	45.60
Hostel (girls)	51.24	55.63	54.74	53.13	53.00	55.74	53.28
Canteens	--	33.40	35.64	34.47	33.97	35.36	34.30
Cafeteria	--	9.33	9.08	8.66	8.47	10.82	9.47
Office buildings	--	42.48	39.37	38.84	38.10	40.47	38.45
Miscellaneous	10	30	28	28	27	30	28
Total	**104.69**	**218.42**	**212.44**	**207.9**	**204.66**	**219.98**	**209.10**

Therefore total amount of solid waste generated per day is recorded as 196.74kgs or 0.1967 tonnes. The values from the above shows that the amount of solid waste generated is more on the weekends i.e. Friday and Saturday But on Sunday the waste generated is very less since, it is a general holiday wherein all activities is shut down everywhere except, in hostels. On Monday and Tuesday the quantity of solid waste generated is more and on Wednesday and Thursday the quantity of solid waste generated is comparatively less than other days.

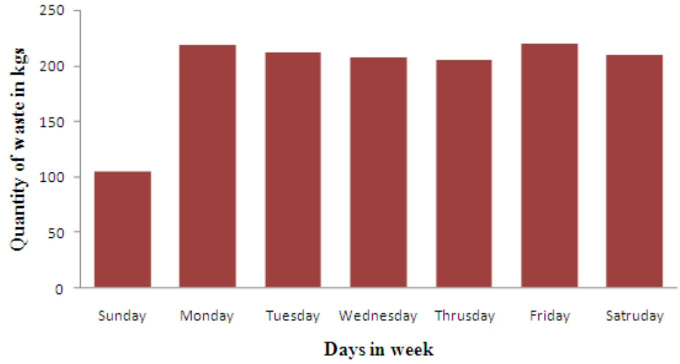

Fig.3. Variation in generation of solid waste in a week.

Composition of the solid waste: The composition and characteristics of municipal solid wastes vary throughout the world. Even in the same country it changes from place to place as it depends on number of factors such as social customs, standard of living geographical location, climate etc. Solid waste is heterogeneous in nature and consists of a number of different materials derived from various types of activities.

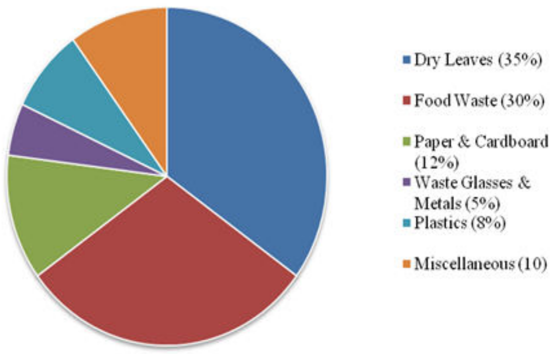

Fig.4. Various Compositions of the solid wastes.

Fig 4 shows the composition of the solid waste generated inside the campus. From the graph it can be seen that with 35% of total weight is dry leaves and twigs constituting maximum quantity of waste generation, since there is more fall of dry leaves almost in all seasons except in monsoon season. Food waste constitutes about 30% of total weight and is almost similar on all the days. Metal, glass, and plastics are generally present although not always so, the relative proportions depending on local factors. Miscellaneous includes rubber, textiles, and ceramics etc. which are present in very less quantity.

Characteristics of solid waste: The physical characteristics of solid waste in the campus are shown in the Table III it can be seen that, compostable matter which include dry leaves and food waste is found to be higher compared to other materials. It constitutes about 140-145 kgs. Other materials constitute the remaining 70-75 kgs. The moisture content is 8%, The chemical characteristics of the solid waste generated in the campus are presented below in the Table IV and are represented on the basis of dry weight. It can be seen that pH of the solid waste is 6 which is slightly acidic. Volatile matter is 1.7%, carbon content is 3.5%, Phosphorous and potassium is 0.80% and 0.89% respectively, nitrogen is 0.67% and C/N ratio is 5.04.

Table III: Physical Characteristic

Table IV: Chemical Characteristics

Materials	Quantity in kg per day
Moisture Content	08
Paper & Cardboard	2-4
Plastics	5-6
Milk covers and other covers	0.5-1
Metal	1.5-2
Glass	1-1.5
Miscellaneous	14-15
Compostable matter	140-145

Parameters	% by Dry Weight
pH	6
Carbon Content	3.50
Volatile Organic Matter	1.70
Nitrogen	0.67
Phosphorous	0.80
Potassium	0.89
C/N Ratio	5.04

Nutrient Analysis of the Vermicompost: Nitrogen, Phosphorous and Potassium which are considered as the most important nutrients in the Vermicompost were analyzed. Nitrogen was analyzed using Kjeldhal method, Phosphorous using colorimetric method and potassium by flame photometry method. pH was tested after 30 and 60 days and it was found to be 7.4 and 9.1 respectively, which indicates that pH tends to go alkaline as the compost process goes on. Also Electrical conductivity was found out to be 2.3 and 5.44 respectively after 30 and 60 days. The results are as shown in the Table V.

Plate.3. Vermicompost Obtained after 60 days

V: Nutrient Analysis of Vermicompost Obtained

Nutrients	After 30 Days (% by dry weight)	After 60 days (% by dry weight)
Nitrogen	3.44	3.87
Phosphorous	1.05	1.66
Potassium	2.68	3.12

The results show that as the compost process continues the nutrients content in the compost increases gradually. The values of NPK indicate that the compost will be very good manure and can be used for the gardens inside the campus.

V. CONCLUSIONS

From the work carried out on the solid waste management in this study, it is found that the total quantity of waste generation in the campus is approximately 200kgs per day or 0.2 tons per day. From the physical characteristics results, it is evident that Food waste from hostels and the dry leaves constitute the major composition in the total quantity of waste generated. Food wastes and dry leaves with high compostable matter indicate that, vermicomposting method is very much suitable for the disposable of the solid waste. Lessons learned from the pilot scale study can be incorporated into the full scale vermicomposting in a PPP model. The greatest opportunity to involve the private sector lies in having firms provide collection services under a contract with the local government since it results in the lowest collection cost, is a common practice in many communities, and there are no long-term impacts from any wrong-doing of the private firm. Concession agreements provide a reasonable option for waste treatment and disposal facilities [24].

However, it would be desirable for analysts, policy-makers, and practitioners to evaluate the environmental obligations to be met by privatized enterprises, establish detailed impacts of monitoring plans of PPPs, develop performance indicators, and conduct a cost–benefit analysis to assess the difference between the various forms of PPPs and define the least expensive and most effective option. A legal framework, allowing the widening of ownership, preventing its concentration, and encouraging competition, must be devised. In this context, competitive tendering and complete transparency particularly with regards to financial accountability are essential elements [24]. Based on the case study carried out at SJCE campus, similar full scale design in PPP model can be initiated at ULB levels to bring out an effective waste management setup.

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