R4D PROJECT:

CHALLENGES OF MUNICIPAL WASTE MANAGEMENT: LEARNING FROM POST-CRISIS INITIATIVES IN SOUTH ASIA

PROJECT WORKING PAPER #13

EVALUATION OF THE EFFICACY AND SUSTAINABILITY OF MUNICIPAL SOLID WASTE MANAGEMENT SYSTEM IN KAMALESWARAM WARD OF THIRUVANANTHAPURAM MUNICIPAL CORPORATION, KERALA, INDIA

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LIST OF ABBREVIATIONS

Abb.	Expansion
CE	Circular Economy
DSWM	Decentralized Solid Waste Management
DSS	Decision Support System
GIS	Geographic Information System
HDPE	High Density Poly Ethylene
HKS	HarithaKarmaSena
IEC	Information Education Communication
IE	Industrial Ecology
IS	Industrial Symbiosis
ISWM	Integrated Solid Waste Management
LDPE	Low Density Poly Ethylene
MRF	Material Recovery Facility
MCF	Material Collection Facility
MSWM	Municipal Solid Waste Management
PP	Poly Propylene
SWM	Solid Waste Management
TPD	Tonnes of Plastic Per Day
UN-SDGs	United Nations Sustainable Development Goals

1. BACKGROUND

Effective Municipal Solid Waste Management (MSWM) is the cornerstone of urban sustainability and environmental protection. As urbanization continues to surge, the management of Municipal Solid Waste (MSW) has become a crucial challenge in maintaining the well-being of both citizens and the environment. MSW management has become increasingly crucial and immediate service delivery of the local self-governments especially in developing economies. MSW management depends on a number of factors, such as a national policy and legal framework, the institutional setup, the application of appropriate technologies, operations management, financial management, public participation, and awareness (Shekdar, 2009). Dedicated MSW management creates job generation on the one hand and liveable, healthy environment on the other hand.

The waste management systems in developing countries are plagued by limited financial resources, lack of proper governance by the municipal administration, improper application of technology, reluctance to adopt state of the art technologies and above all absence of adequate institutional mechanism. In order to manage MSW, the integration of various phases of management (sorting, collection, transport, and final destination) is paramount.

The problem managing MSW is particularly challenging for cities in developing countries (Selin, 2013; Taiwo, 2011) and especially for local self- governments that are mandatorily responsible for managing waste (Solberg, 2012).

Economic growth, population rise, increasing urbanization and the related acceleration of consumption leads to increased waste generation. It is estimated that the volume of MSW could double from current levels of 1.3 billion tonnes annually to 2.6 billion tonnes by 2025 (World watch. Global Municipal Solid Waste Continues to Grow. Available online: http://www.worldwatch.org/global-municipal-solid-waste-continues-grow-0 (accessed on 2 September 2023) by Keith Barker, July 30,2012.

As per World Bank reports vast amounts of uncollected waste is dumped in urban areas; estimates suggest between 40% and 70% of discarded materials remaining uncollected (United Nations Environment Programme (UNEP). Integrated Solid Waste Management. Available online: http://www.unep.org/gpwm/what-we-do/integrated-solid-waste-management (accessed on 11 September 2023).

1.1 Solid waste Management in India

According to Solid Waste Management Rules, 2016 solid waste means and includes solid or semi-solid domestic waste, sanitary waste, commercial waste, institutional waste, catering and market waste and other non -residential wastes, street sweepings, silt removed or collected from the surface drains, horticulture waste, agriculture and dairy waste, treated bio-medical waste excluding industrial waste, bio-medical waste and e-waste, battery waste, radio-active waste generated in the area under the local authorities and other entities. In India, the management of municipal solid waste is the mandatory responsibility of urban and rural local bodies, but it is an established fact that the local bodies are often unable to perform their duties effectively because of lacking in-house capacity to handle the complexities of the process.

The status of Solid Waste Management (SWM) in India is marked by a complex mix of challenges, progress, and ongoing initiatives. India has a regulatory framework for SWM in place, including the Solid Waste Management Rules, 2016. These rules emphasize source segregation, waste processing, and environmentally sound disposal practices. However, the effective implementation

of these rules varies across states and cities. Compliance with regulations is still a challenge in many regions. The National Government in recognising the issue of waste management released various Acts for streamlining the SWM system in the country. In 2016, six waste management Acts came into effect.

Municipal Solid Waste (MSW) generation in urban areas has been increasing at an alarming rate, straining existing waste management systems. The total quantity of Solid waste generated in the country is 160038.9 TPD of which 152749.5 TPD of waste is collected at a collection efficiency of 95.4%. 79956.3 TPD (50 %) of waste is treated and 29427.2 (18.4%) TPD is landfilled. 50655.4 TPD which is 31.7 % of the total waste generated remains un-accounted (CPCB, 2022).

Per capita solid waste generation for the years (2015-16 to 2020-21) shows an increase from 118.68 gm/day to 119.07 gm/day. Marginal decreasing trend is observed in per capita solid waste generation over the same period. Increasing trend in percentage of solid waste processed has been observed during the last six years wherein percentage of solid waste processed has increased from 19% in 2015-16 to 49.96% in 2020-21. Decreasing trend in gap in solid waste management has been observed up to 2019-20 during the last six years wherein percentage gap in Solid Waste Management has decreased from 40.99% in 2015-16 to 25.82% in 2019-20 and slightly increased to 31.70 % in 2020-21. Decreasing trend in solid waste landfilled has been observed during the last six years wherein solid waste landfilled has decreased from 54% in 2015-16 to 18.4% in 2020-21 (CPCB, 2022). This is a healthy sign of waste management that diversion of waste from landfilling to other methods of disposal has been becoming more popular.

Several cities and regions in India have been exploring sustainable SWM solutions. This includes decentralized waste management, community composting, and the promotion of eco-friendly products. While India has made strides in addressing SWM challenges through policy measures and awareness campaigns, significant gaps and challenges persist. Sustainable and efficient waste management practices, including recycling and proper disposal, remain a priority. Strengthening infrastructure, improving regulatory compliance, and engaging communities are critical steps toward achieving sustainable and environmentally responsible SWM across the country.

1.2 Solid waste Management system in Kerala

Upon the introduction of 74th Constitutional Amendment in 1994 started with a devolution of responsibility for MSWM from central to local government. The Kerala government transferred functions, budget, and personnel to local governments, which means local governments now play a lead role in the management of solid waste within their jurisdictions. There is limited data about the specific amount of waste generated in individual municipal corporations and municipalities and in grama panchayats.

In Kerala, there are 93 Municipal Authorities (6 corporation and 87 Municipalities) responsible for MSW management. Nearly 3543 TPD of MSW generated in the State, out of which 964.76 TPD waste is collected and 2550 TPD waste is treated. There are 2 large and 12 small, centralized windrow composting plants and 7 vermi composting plants setup in the State. One landfill site has been identified in the State and total 41 dumpsites have been reported (CPCB, 2022). Bio-mining of legacy waste has been completed at Kureepuzha, Kollam dumpsite, work started at Njalianparmbu, Kozhikode dumpsite and Chelora dumpsite, Kannur (The Hindu Jan 27,2022)),(KSPCB,NMCG Jun 2021).

As per estimates, Kerala generates around 11,449 tonnes of solid waste per day, of which around 3,521 tonnes is generated in urban areas and 7,928 tonnes in rural areas. The local bodies in Kerala

are struggling to ensure scientific disposal of garbage owing to lack of infrastructure and a proper end-to-end system (Kerala State Environment Plan 2022) Decentralised waste management is the current policy of the Kerala government. But for 100% solid waste management, certain centralized facilities are necessary including landfills to ensure the waste management cycle is complete.

(https://www.newindianexpress.com/states/kerala/2022/aug/04/keralas-solid-waste-management-project-faces-major-challenge-2483823.html) (KSWMP Report, June 2020)

1.3 Solid waste Management system in Thiruvananthapuram Municipal Corporation

Centralised to decentralised approach

TMC lacked a proper plan for managing the MSW generated in its limits till the commencement of Vilappilasala centralized plant in the year 2000. TMC was planning for a centralized plant for managing the entire MSW generated in its limits even before the Committee appointed by the Supreme Court of India to give suggestions for the improvement of urban solid waste management and the recommendations of this committee leading to the enactment of SWM Rules of 2000. TMC enhanced their door-to-door collection services of waste from the houses in the then 76 wards and collection of waste from dumping points and waste bins for transferring it to the centralized plant. The plant was established in a nearby village which was beyond the limits of the jurisdiction of the city corporation. A few years after the establishment of the plant the nearby communities started facing severe health and environment degradation issues mainly due to the improper functioning and absence of leachate treatment plant and proper landfill.

The centralized Windrow composting plant for the treatment of biodegradable waste established at Vilappilsala has met with various issues including public protest. Due to public protest transport of municipal solid waste to the processing plant was stopped since November 2011 and the centralized plant was closed down.

Since the closure of centralized plant'at Vilappilsala, TMC was in the verge of facing a health pandemic due to the condition of putrefying piles of garbage in the city road sides and vacant lands. It was assumed that if such condition persisted, TMC could have faced an health pandemic as happened in Surat during the year 1994 (Choudhury, 2017). As the situation started worsening, in its desperate attempt to find solutions TMC started to consider alternatives. Then the Municipal Corporation embarked upon decentralized treatment options like source level treatment and community level treatment for the biodegradable portion of solid waste. In this approach, food waste will be treated at source and inorganic waste will be segregated at source prior to its transfer for recycling.

As part of decentralized waste management, Aerobic Composting Units (Thumbur Muzhi model composting Units) were established in different parts of the city and also set up large size (I to 2 tons per capacity) community level biogas plants in various markets. In order to promote source level treatment at household's various types of composting units including kitchen bins and portable models of biogas plants are also being encouraged at household level. Increased subsidiary to the tune of 90% for different type of compost units and 75% subsidiary for biogas plants are being given for promoting source level treatment of solid wastes generated at households.

TMC has travelled a long way in its MSWM activities. It has actually led an experimentation for Kerala's first centralized MSWM model and for a comprehensive decentralized MSWM model. Even though the centralized model miserably failed, the situation paved the way for the adoption of

decentralized model for MSWM. Now, the current situation and status of the SWM management in TMC needs to be thoroughly analysed and examined with respect to the infrastructures established, effectiveness, sustainability and the services delivered as well as the perspective of stakeholders associated with MSW management.

In a bid to reduce the volume of waste going to the municipal steam TMC encourages households to separate recyclables and handover to Haritha Karma Sena (HKS) and compost organic waste at source. To date, these approaches have not been completely successful. The challenges of waste management for TMC can be identified through the case study proposed to be undertaken one of its wards, Kamaleswarm.

The objectives of this study encompass multiple dimensions of waste management, including waste composition analysis, assessment of source segregation practices, evaluation of collection and transportation efficiency, scrutiny of waste processing methods, and an examination of the environmental and social implications of these practices. Along with this the engagement of the local community and the role of green volunteers (Haritha Karma Senna) in shaping the waste management landscape within Kamaleswaram Ward is also looked into.

As already stated, Kamaleswaram Ward in Thiruvananthapuram Municipal Corporation is selected as the study area for the present efficacy study. The study aims a comprehensive evaluation of the MSWM system in the Kamaleswaram Ward, delving into the intricacies of waste generation, collection, transportation, processing, and disposal. The study aims to provide a detailed and data-driven analysis of the prevailing waste management practices within the ward, with a specific focus on their effectiveness, sustainability, and alignment with environmental and regulatory standards.

Many techniques, tools, and models have been applied to assess this integration and the quality of MSW management. Some evaluations have been implemented based on applying sustainability indicators to assess and improve the MSW management system from different perspectives. The applicability of indicators for assessing the sustainability of a MSW management system is studied by many researchers for example, studies conducted in India (Rana et al 2015), Romania (Căilean and Teodosiu,2016) and Italy emphasizes the applicability of indicators. Of all the indicators that can be applied for sustainable municipal solid waste management, it is very important to develop an appropriate policy and implementation plans to diminish the amount of waste generation by setting a system for waste separation at source and by educating citizens to raise their awareness of waste classification (Yukalang,et al, 2018).

In conjunction with site visits, observations, and secondary data analysis to determine the specific waste management issues facing the ward, semi-structured, one-on-one interviews and data collection through questionnaire survey were conducted to further investigate and understand the perspectives of local stakeholders. Additionally, integration of GIS and MCDA are also made to get more output. The integration of GIS and MCDA is a powerful tool to offer solutions for efficient and sustainable solid waste management problems because GIS provides efficient manipulation and presentation of the data and MCDA helps decision making easier for the authorities.

The important application of GIS in solid waste management includes site selection of waste management system, finding locations for placing collection bins, effective route tracking, establishing the drive time bands.

The aim of this study is to comprehensively assess the effectiveness and sustainability of the MSWM system within the specific geographical area of Kamaleswaram Ward in Thiruvananthapuram

Municipal Corporation, with the primary goal of contributing insights and recommendations to enhance the overall waste management system in the ward.

1.4 Objectives of the Study

1.4.1 Major objective

The major objective of this study is to evaluate the effectiveness and sustainability of the SWM system in Kamaleswaram ward in Thiruvananthapuram Municipal Corporation

The following specific or sub objectives are employed for the assessment of sustainability.

1.4.2 Specific Objectives

- To quantify and characterize the volume and composition of municipal solid waste generated within Kamaleswaram Ward over a specified time frame.
- To evaluate the extent of source segregation practices among residents and businesses in Kamaleswaram Ward.
- To determine the level of compliance with waste segregation guidelines and regulations
- To assess the efficiency and effectiveness of waste collection services, including the coverage, frequency, and reliability of collections and source level management
- To measure the attitude of the Human resource involved in the waste management.
- To study the level of satisfaction among households towards the SWM system in the ward
- To apply GIS tools for the identification of waste bin locations and sorting platforms in the ward
- To apply GIS tools and remote sensing for the hydrological study of KariyalThodu, the main drainage, in the ward and an assessment of the dumping of waste in the drainage

The present project undertakes a study to understand the applicability of GIS and MCDA to evaluate the efficacy and sustainability of the SWM system in the Kamaleswaram Ward of Thiruvananthapuram Municipal Corporation.

2. REVIEW OF LITERATURE

Waste collection and transfer operations constitute an important part of the solid waste management cost (Rada et al., 2013; Boskovic and Jovicic, 2015). Determining the most suitable locations for waste bins is a process that requires multiple criteria to be evaluated together. The factors to be considered for the location of waste collection bins arrived through interviews with the municipal authorities and citizens are walking distance, waste bin quantity, waste bin volume and population density. Based on the selected criteria and using GIS, the most suitable waste bin's locations were determined (Terzi et al, 2020).

One study illustrates a geographic information system (GIS) based algorithm for optimal location and number of storage bins, considering p-median constrained model, based on Indian guidelines for Municipal Solid Waste Rules. The algorithm also computes the contributing command area of solid waste to a particular bin, based on the shortest distance, with descending slope for ease in solid waste collection (Vijay et al, 2008).

Much research has been done to define sustainable decision-making models to evaluate waste management alternatives such as life-cycle assessment (LCA), cost–benefit analysis, and multi-criteria decision analysis (MCDA) (Milutinovićet al, 2014). LCA examines the environmental influence of all processes of the waste handling from "cradle to grave"; cost–benefit study analyzes the financial dimension, while multi-criteria decision analysis (MCDA) examines economic, social, and environmental criteria (Morrissey and Browne, 2004).

MCDA is often used in waste management, and this methodology is appropriate for appraising the sustainability of a waste management system. The advantage of multi-criteria analysis in evaluating the sustainable alternative is that it enables the application of both quantitative and qualitative criteria. It also permits the cooperation of various groups of decision-makers, even with contradicting intentions in determining indicators and decision-making. The conducted literature review has revealed that MCDA is quite regularly applied as a decision-making model in waste management. In this paper, an evaluation of alternative methods for MSW management in Kamalewaram Ward of Thiruvananthapuram Municipal Corporation is attempted. Alternate methods are compared based on MCDA. The main aim of this article is to rank and find the most sustainable municipal solid waste management alternative for the wardbased on waste composition by using MCDA. A model based on MCDA—the AHP (analytic hierarchy process), is developed. The model is tested in a case study of the Municipal Solid Waste Management System of Kamalewaram ward.

Alternative scenarios of MSW management in Mexico City were compared and analyzed based on MCDA to determine the most sustainable scenario for the city. The comparison was based on waste composition, experts' opinions, and overall assessment of state-of-the-art technologies, by using MCDA. The study attempted to visualize and compare the economic benefits, the impact of waste treatments on the environment, and social benefits of specific waste technologies for Mexico City (Tsydenova, 2018). In another study, alternative methods for MSW management in Hanoi were compared based on MCDA to rank and find the most sustainable municipal solid waste management alternative for Hanoi based on waste composition and experts' opinions by using MCDA.

3. MATERIALS AND METHODS

To elucidate the sustainability aspects in the evaluation of SWM system in the study area tools like questionnaire survey, waste quantification and characterisation study as well as use of GIS tools are made use of. The integration of conventional methods with GIS techniques to prepare various thematic layers enhanced the output of the study. GIS software used in this study is ArcGIS 10.2 from ESRI and ERDAS IMAGINE 2013.

The following methodology was adopted in this study:

- Preparation of Survey Questionnaire
- Collection of primary data on waste collection practices with respect to its quantity collected, type and pattern of waste collection with its frequency, storage, recycling, and the financial aspects from the households
- Collection of primary data on waste collection practices with respect to its quantity collected, type and pattern of waste collection with its frequency, storage, recycling, and the financial aspects from Haritha Karma Sena who are deployed in MSWM services.
- Job satisfactory survey was also made among the HKS workers to find the job satisfaction in waste collection.
- Identification and mapping of waste collection points, location of waste transfer points and location of waste management infrastructure with the aid of GIS.

3.1 Study Area

The area of interest for the study is Kamaleswarm ward (ward no. 68) which falls in Thiruvananthapuram Municipal Corporation.

3.1.1 Thiruvananthapuram Municipal Corporation (TMC)

TMC is the largest municipal corporation of Kerala with 100 wards, located between $8^0$21´ 27.509´´ to 8^0 36 ´14.785´´ North latitude and 76^0 50´ 45 .814 ´´to $77^0$1 ´48.037´´ East longitude. It has a population of 955494, with an area of about 214.86 square km. The corporation is characterized by its undulating terrain of low coastal hills and busy commercial valley. The area can be divided into geographical regions, the midlands and lowlands. The lowland is a narrow stretch comprising shorelines, rivers, and deltas dotted with coconut palms. Vellayanilake, biggest freshwater lake in the district is in the suburbs of the city.

Thiruvananthapuram Municipal Corporation generates around 450 tons of solid wastes per day. Based on sample studies it is estimated that about 72% of MSW reaches the municipal stream, 19% gets disposed off at sources and the rest about 9% of the MSW is being collected by the Rag Pickers for recycling. Households generate major share of solid waste (55.4%), and among the remaining sources bulk contributors are commercial establishment and markets (Dileep Kumar,2017)

With rapid urbanisation and population increase a large part of the land cover of Thiruvananthapuram city is turning into built up area. The economic growth among the city dwellers and e-commerce flourishing the city is at a high pace to generate waste than ever before which in turn is placing heavy burden on the city administration to offer sufficient disposal systems.

3.1.2 Kamaleswaram Ward

Kamaleswaram ward of Thiruvananthapuram Municipal Corporation is selected for the present study. Out of the hundred wards in Thiruvananthapuram Municipal Corporation, Kamaleswaram is the 68th ward. Thus, being a part of the Capital of Kerala state. It is of an Area of 128 hectares. It extends vertically from Latitude 8^0 27' 29.448" N to 8^{0}28' 24.27" N and horizontally from Longitude 76^0 56' 9.637" E to 76^{0}57' 3.546" E. There are approximately 1800 residential buildings. Water canal draining the area is Kariylthodu and its tributaries that joins the Parvathyputhanar.

The Kamaleswaram Ward, situated within the Thiruvananthapuram Municipal Corporation in the southern state of Kerala, represents a microcosm of the broader challenges and opportunities facing urban waste management in India. Thiruvananthapuram Municipal Corporation, a rapidly urbanising centre, is faced with the dual demands of managing growing waste volumes while mitigating the environmental impacts associated with inadequate waste disposal practices. The Kamaleswaram Ward, therefore, offers a compelling case study for evaluating the efficacy and sustainability of a MSWM system in a dynamic urban context.

A preliminary assessment of the study area through the ward councillor of TMC revealed that the chosen ward is a representative or typical ward in terms of demographic, geographic and waste generation characteristics. It reflects the general population and waste management challenges of the city as a whole. The ward has a diverse mix of residential and commercial areas making it an ideal location for studying the varied waste management needs. The ward is strategically located in the city as it is very close to the main city Centre, East Fort making it an ideal location to study the MSWM. The ward has specific geographic feature, proximity to water body, the Kariylthodu and its tributaries that joins the Parvathyputhanar which flows through and receives the burden of waste dumping that warrant closer examination. An active community interested in participating in waste management initiatives and providing valuable feedback for the study is another advantage. Out of 50 numbers of problematic wards, Kamaleswaram ward has been identified as one of the problematic ward in terms of waste management in an earlier study (Nimmy Babychan 2021).

3.2 Location Map of Kamaleswarm ward

The location map of Kamleswaram ward which is part of Thiruvananthapuram Municipal Corporation is shown in Figure 1.

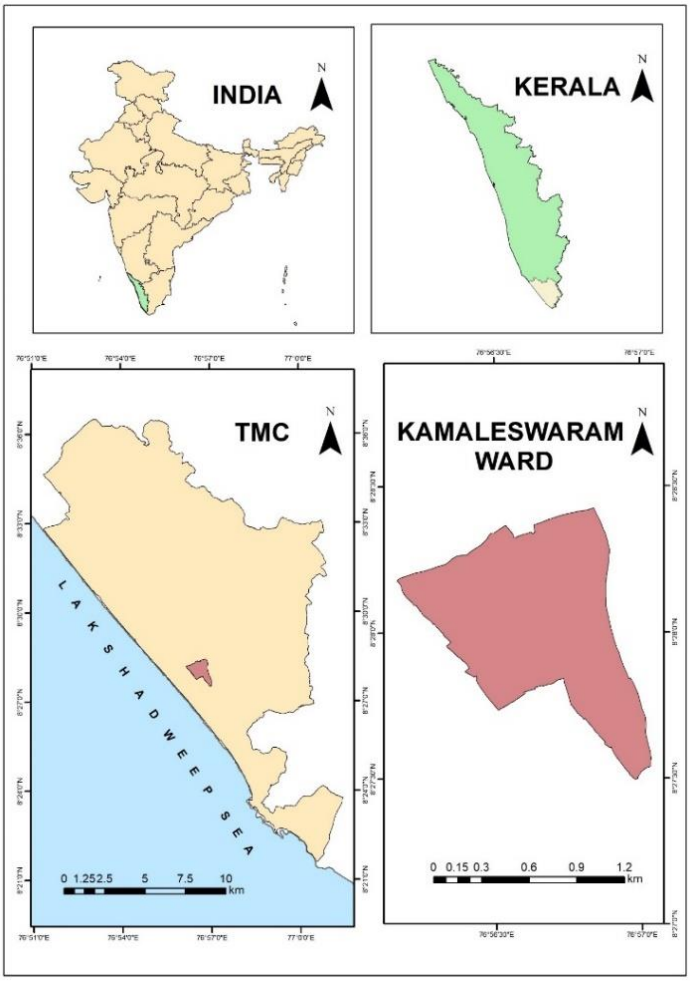

Figure 1 Location Map (TMC: Thiruvananthapuram Municipal Corporation)

3.2.1 Climate

The climate of the study area is generally tropical monsoon or Am of Koppen (1900). Rains are induced by the large forest reserves thus maintaining a comfortable climate. Cold weather is experienced with rising altitude, while warmer down, the weather is bracing and is generally hot in the coastal regions. The mean maximum temperature is 35 °C and the mean minimum temperature is 20 °C. As the district stretches from north to south with the Lakshadweep Sea in the west side, the relative humidity is generally high. It rises up to about 95% during the South-West monsoon.

The total annual average rainfall in the district is about 1,500 mm per annum. The southwest monsoon, from June to September is the principal rainy season which is the major rainy season. The second rainy season is the Northeast monsoon which is from October to November.

The district also gets thunderstorm rains in the pre-monsoon months of April and May. From December to February the average temperature goes down to 20 °C. It is generally considered as the winter season. The summer season starts in February and continues until May with an average temperature of 35 °C.

3.3 Workflow

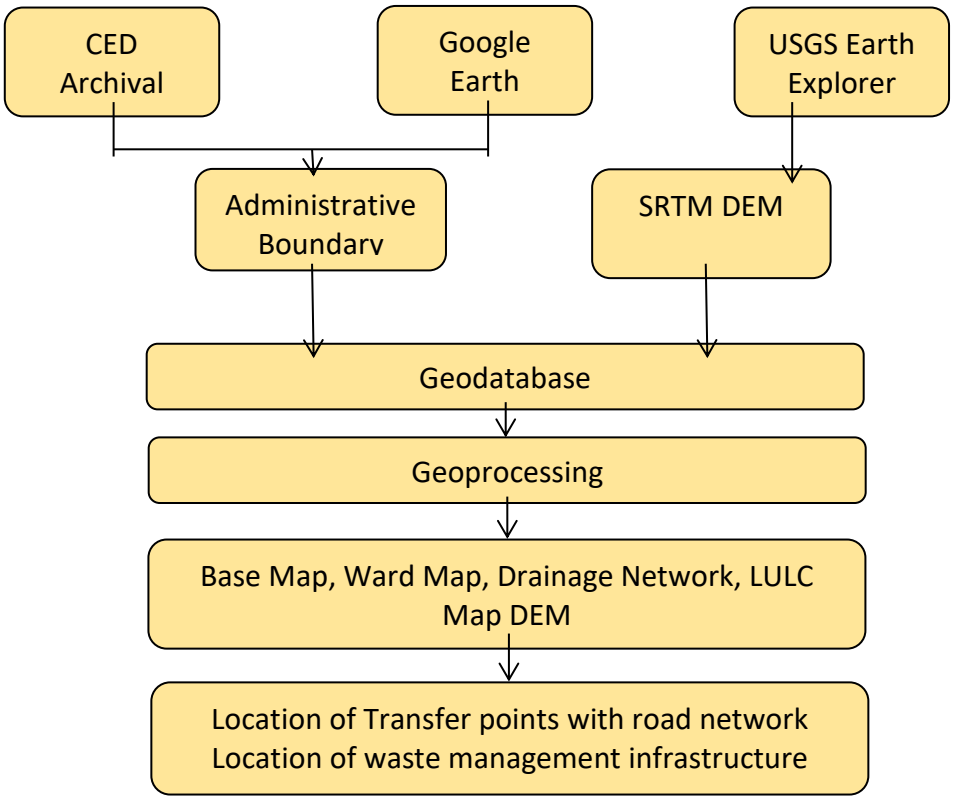

Figure 2 Workflow Diagram of Methodology Adopted for the Study

3.4 ArcGIS 10.2

Application of GIS tools were an important part of the study and is used as an important tool for the planning of Municipal Solid Waste Management. Employing ArcGIS 10.2 the municipal boundary, ward boundary, drainage map, road network map, major land use and land class types were mapped along with MCF locations and waste transfer points locations. Shape files of Thiruvananthapuram Municipal Corporation ward boundary, drainage map, road map, MCF location map were obtained from CED archival data, SRTM (Shuttle Radar Topography Mission), DEM downloaded from USGS website were used for the creation of Digital Elevation Model (DEM) of the study area.

3.4.1 Base map of study area

Base map of the study area has been prepared using the data of ward boundary, major roads, major rivers and water bodies. This map includes all basic information related to the study area.

3.4.2 Land Use Map and Ward Map

The Land Use classes of the study area were obtained from the GOOGLE EARTH PRO scenes. Different land uses like Built-up areas, aground areas, water bodies, ground area were marked with polygons while roads and canals were marked with lines and points of interest were marked with points. Ward Map has been prepared making use of ward boundary.

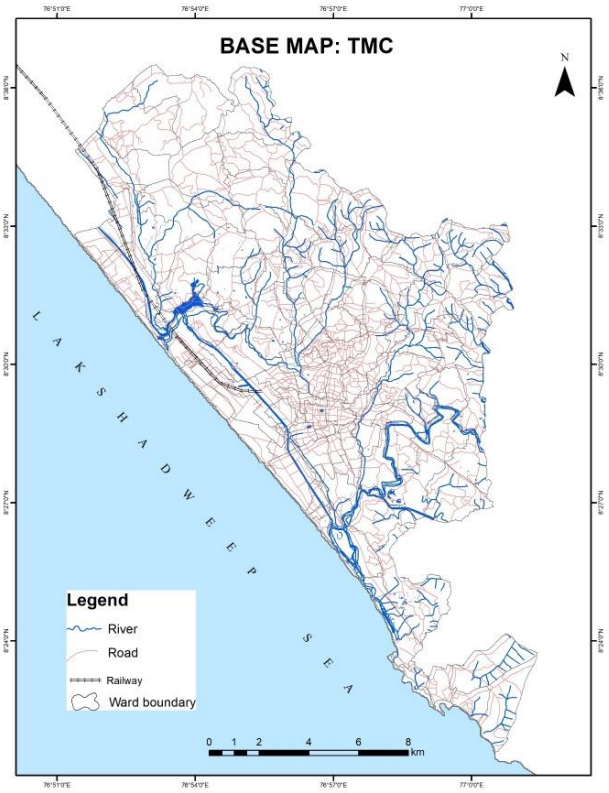

Figure 3 Base Map of TMC

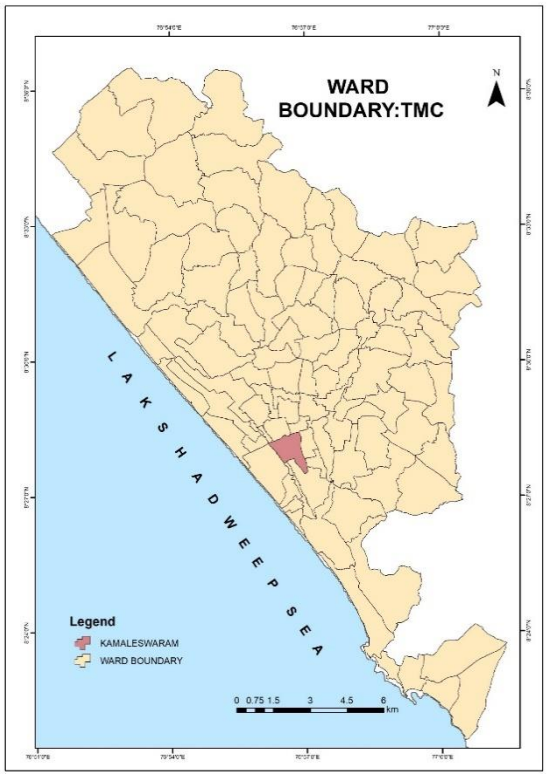

Figure 4 Ward Map of TMC

3.4.3 Digital Elevation Model (DEM)

Digital Elevation Model of the study area is prepared by using GIS tools. SRTM from USGS is used for the data.

3.4.4 Location Transfer points

The locations of transfer points were taken using GPS. These are also the points where the Solid Waste is kept by the collection crew and segregation is made. The waste storage bins were marked on the road network.

3.4.5 Location of waste management infrastructure

GPS locations of waste processing sites and MCF/ MRF were taken and plotted.

3.5 Evaluation of Efficacy and Sustainability

3.5.1 Questionnaire survey

For the study of the SWM system in the ward a questionnaire survey was employed. The participants in the survey included the members of the Haritha Karma Sena involved in the waste collection.

Haritha Karma Sena, also known as the Green Corps or Haritha Karma Sena (HKS), is an important initiative in waste management and environmental conservation in the state of Kerala.

Haritha Karma Sena is formed with the primary goal of involving local communities, especially women and unemployed youth, in waste management and environmental conservation activities. The program seeks to create sustainable employment opportunities for individuals at the grassroots

level while addressing environmental concerns related to waste management. One of the key roles of Haritha Karma Sena members is waste collection. They collect and segregate waste at the household level, ensuring proper separation of recyclables, biodegradable waste, and non-recyclables.

The questionnaire was used to collect information regarding the waste collection practises followed, quantity of waste collected, type of waste collected, the frequency of collection, time of collection, number of houses covered etc. The questionnaire also gathered information related to the satisfaction among the members involved in waste collection. The sample population included all the 13 Haritha Karma Sena members in the ward. Data was collected through personal interviews by the researcher himself meeting them during their working hours.

Survey was also conducted among the households. 100 houses were randomly selected from the 1800 houses in the ward for collecting information. All the 100 houses were personally visited by the researcher and information gathered through direct interviews and marking the responses at the time of data collection. The questions included the method of segregation, type of waste management practised, quantity of waste generated. Questions were also asked to gather the level of satisfaction of the households the present waste management system and cleanliness of the premises. Waste quantity assessment was done by direct weighing of the samples collected every day for one week.

4. RESULTS AND DISCUSSION

4.1 Land Use and Land Cover (LULC)

The major land use types found in the study area are built-up area, vegetation, water bodies and open lands. Most part of the land is built-up which depicts the level of urbanization.

4.2 Digital Elevation Model (DEM)

The digital representation of the topographic surface with respect to any reference datum is known as a digital elevation model (DEM). It is the most basic type of topographic digital representation. It is used to determine terrain features including drainage, basins and channel networks as well as terrain variables like elevation at every point, slope, and aspect. DEMs are frequently utilised in hazard monitoring, natural resource exploration, hydrologic and geologic study, agricultural management, planning and siting of SWM infrastructures etc.

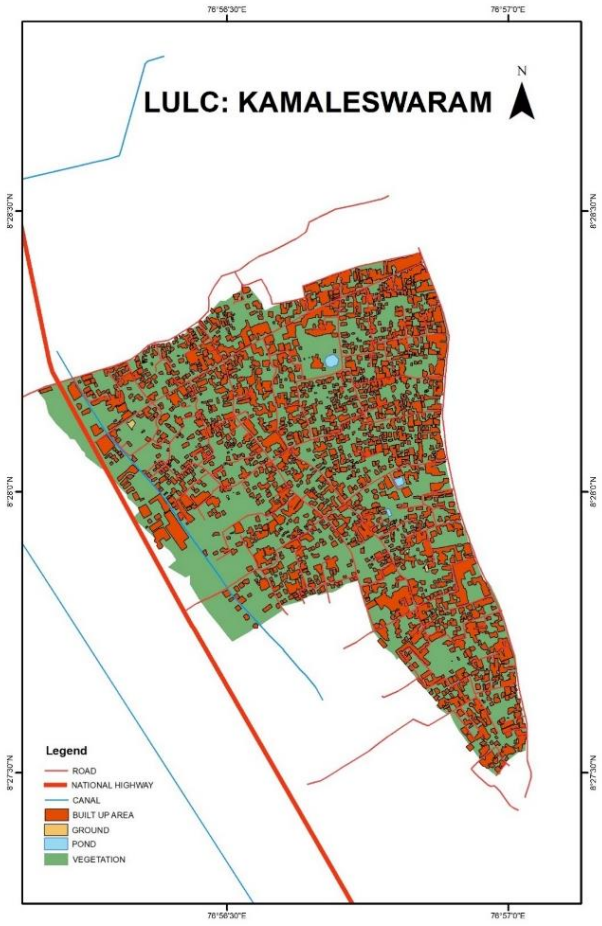

Figure 5 LULC of Kamaleswaram ward

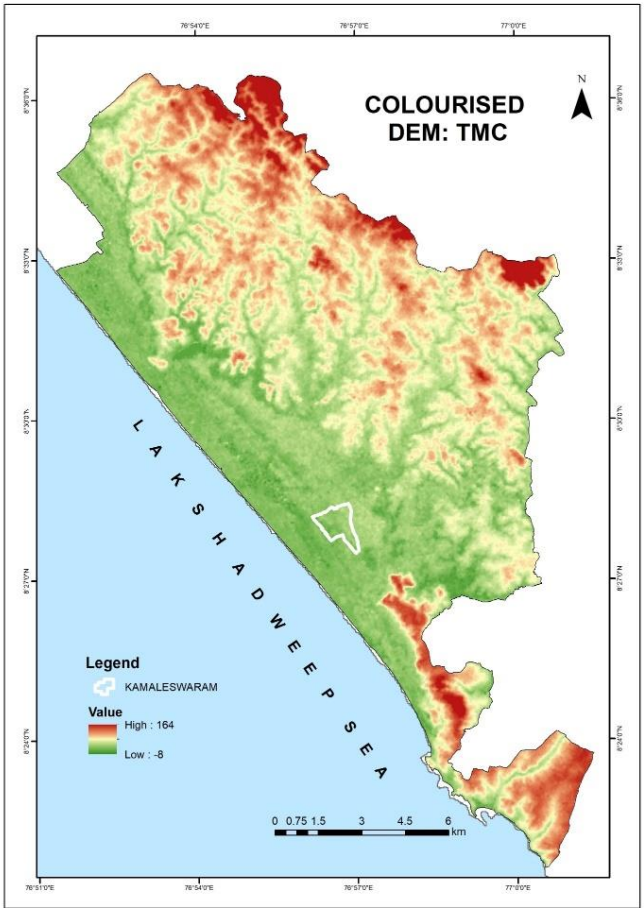

Figure 6 DEM of TMC

4.3 Evaluation of Efficacy and Sustainability

Based on the survey and secondary data and interviews the following observations were made and analysed to evaluate the efficacy and sustainability of MSWM in the ward.

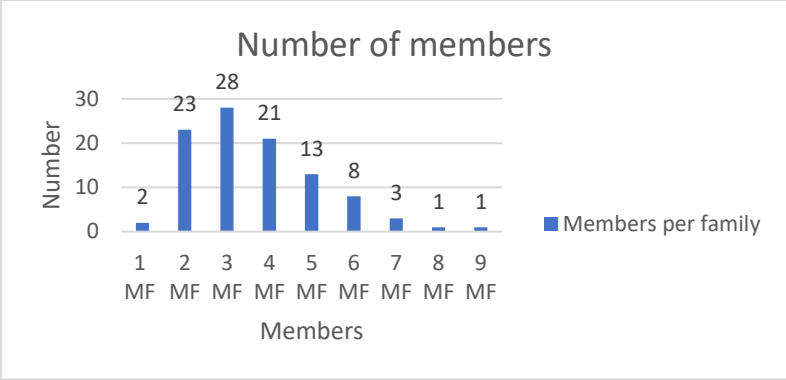

Figure 7 Number of members per family

The number of family members ranged from one to a maximum of 9. Families having members of 2, 3 and 4 constituted 72% of the population. 3 member families were the highest with 28 percent.

10% of the households were having children below 5 years age and among them 2% households have 2 children each below the age of 5. We could infer from this data that the generation of waste particularly plastic toys and sanitary (diaper) waste will be higher in these households compared to the rest.

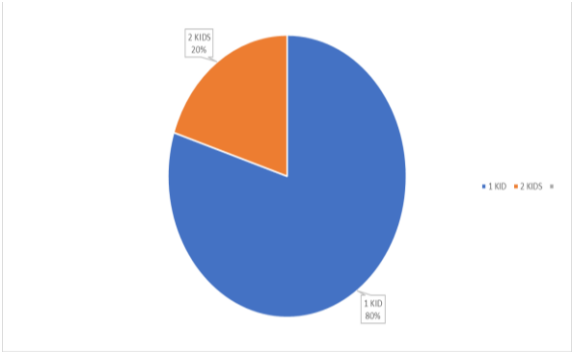

Figure 9 Number of family having children below 5 years of age

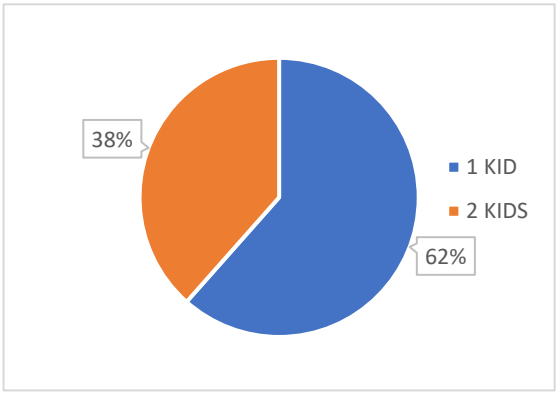

Figure 8 Houses having children in the age group 5 to 10 years in percentage

13% of the houses had at least one child between the age limits 5 to 10. Out of this 13%, 62 percentage of houses had one child and 38 percentage of houses had two children. It could be inferred from the data, that generation of waste will be more in these houses because of the habit of wasting food usually noticed in children.

Among the samples studied only a small percentage (15%) were below poverty line (BPL) while majority (85%) in the study area were above poverty line.

Therefore, can infer that if provided proper guidelines and the impact majority of the sample can adopt to sustainable source level composting of biodegradable waste and reduce the load over centralised composting.

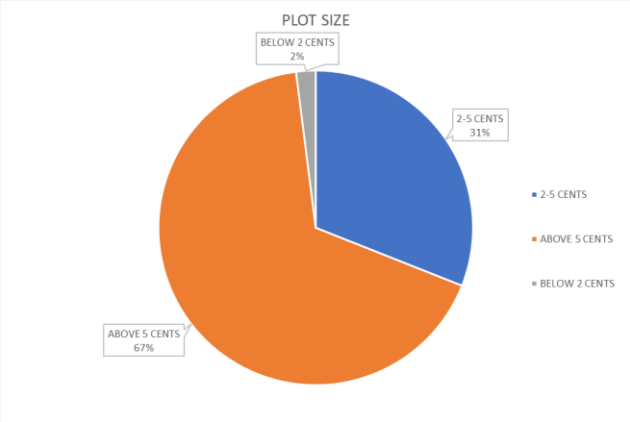

Figure 10 Size of plot

67% of the households in the study area had more than 5 cents of parcel and only 2% were having below 2 cents of land. The rest were having space between 2 and 5 cents. From this we can infer that the source level disposal can be implemented in majority of the households in the study area.

89% of the sample possess own houses and only 11% were living on rented property. This also shows that if motivated, the owners could install biogas plants or other modes of source level waste disposal.

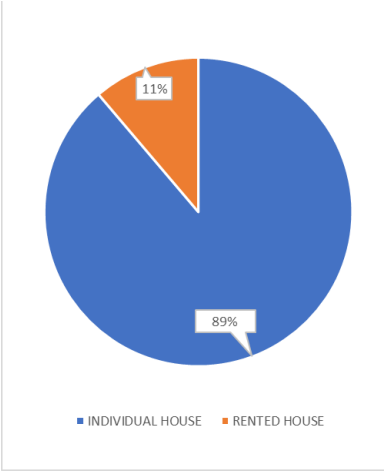

Figure 11 Dwelling type

People from all steams of work are dwelling in the study location. Businessmen and private employees are the majority. From this observation, we can infer that majority of the sample population is self-dependent and financially sound.

More than half of the sample responded that both male and female members of the household share responsibility for managing the waste. From this observation, we can infer that there is no gender discrimination in managing household waste.

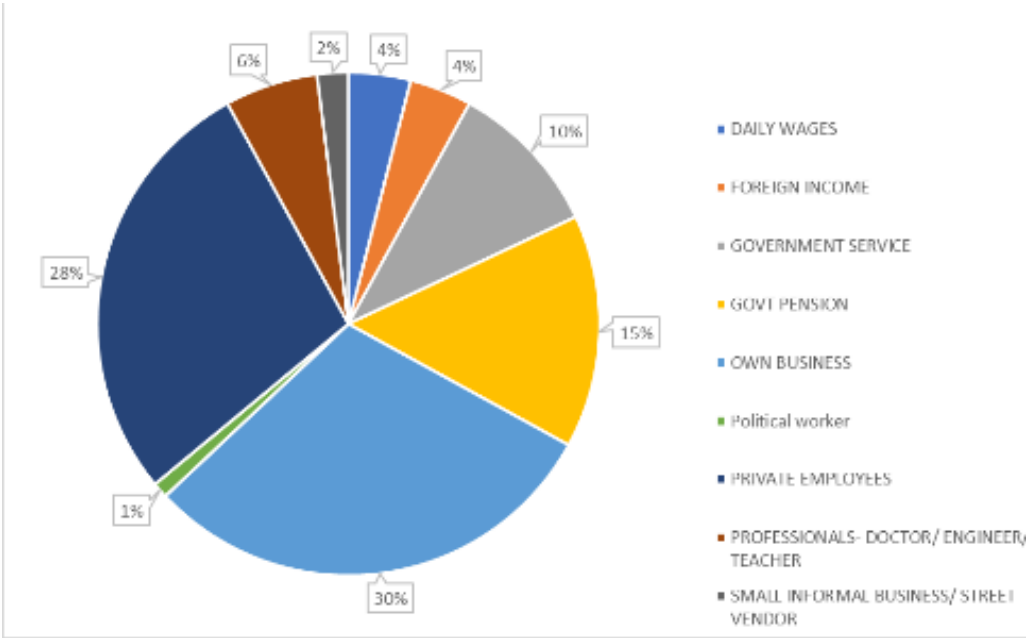

Figure 12 Primary source of income

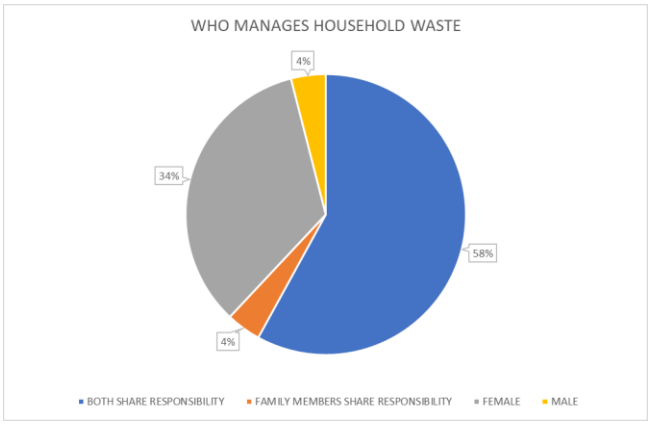

Figure 13 Sharing Responsibility of HH waste management

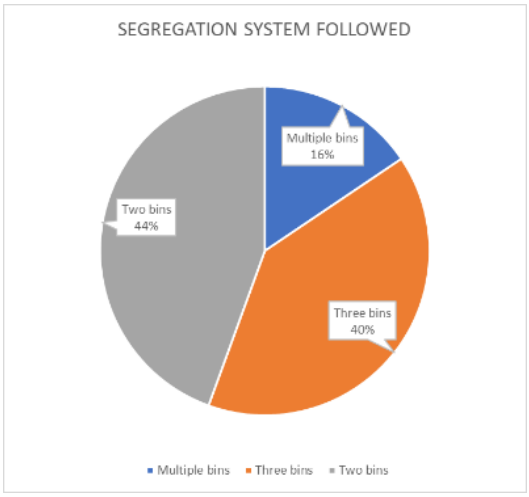

Figure 14 Bin system adopted

Two bin and three bin systems are the mostly followed segregation system. Multiple bin system is followed by 16% of households. We can infer that all the waste except biodegradable wastes are disposed together.

Kitchen waste is disposed of mainly by the Haritha Karma Sena Wokers. Others use biogas plants, compost pits, kitchen bins, pipe compost, gardening, and even feed their pets mainly chicks, dogs and cats. There were some areas from where the Haritha Karma Sena do not collect waste.

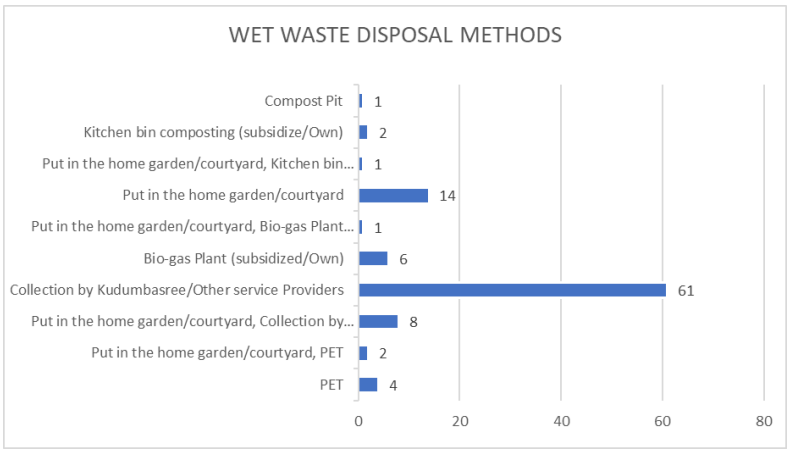

Figure 15 Disposal of Wet Waste

Some among the samples have resorted to online newspaper which is the future of news reading. While majority is reading the traditional way. The paper waste is being sold to scrap dealers who pick them from home.

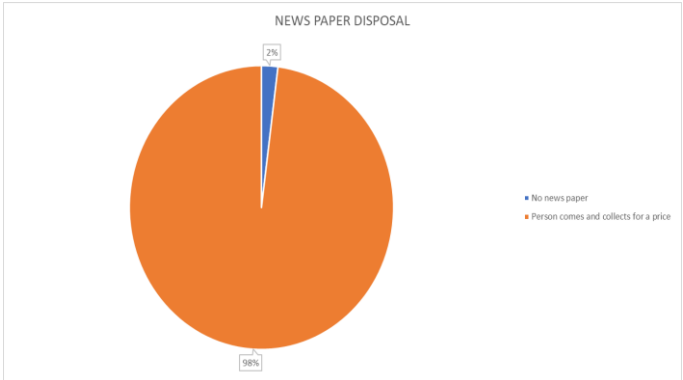

Figure 16 News Paper Disposal

Majority of the respondents produced less than 150 gm generation of plastic waste per week. While a few responded with around 300 gm per week generation of plastic waste. Large portion of the sample depend on Haritha Karma Sena or Scrap dealers for the disposal of plastic waste. While a few deposits them at the Collection centre of Corporation. The third category uses both on their convenience.

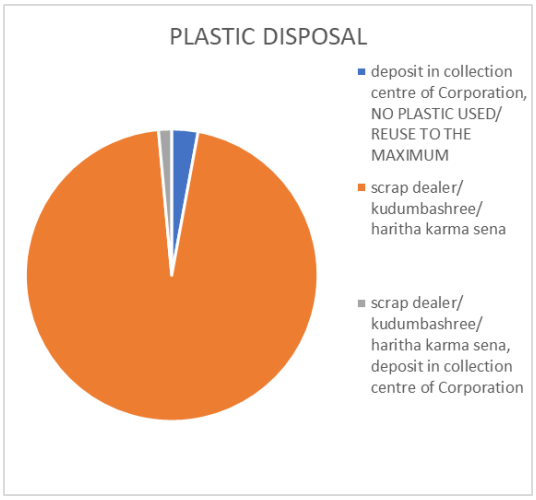

Figure 17 Plastic waste disposal

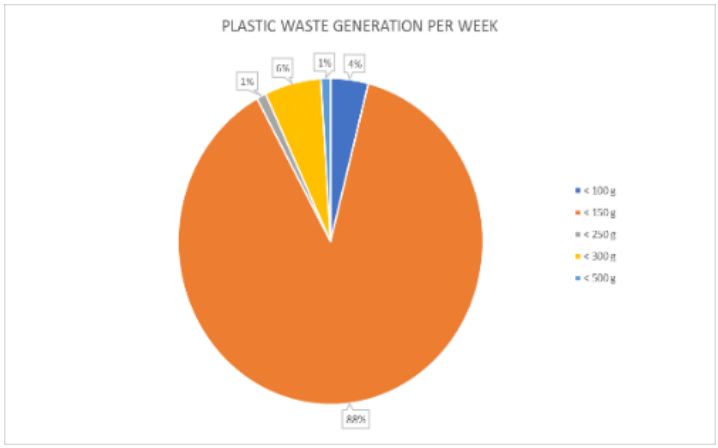

Figure 18 Plastic waste generation per week

Out of the 100 households only 22 responded as using sanitary materials. Among them only one is using reusable menstrual cup and the rest were using disposable sanitary pads. Majority of the users responded that they burn them after use while rest commented that cleaned pads were sealed in tight packing and given to Haritha Karma Sena Workers.

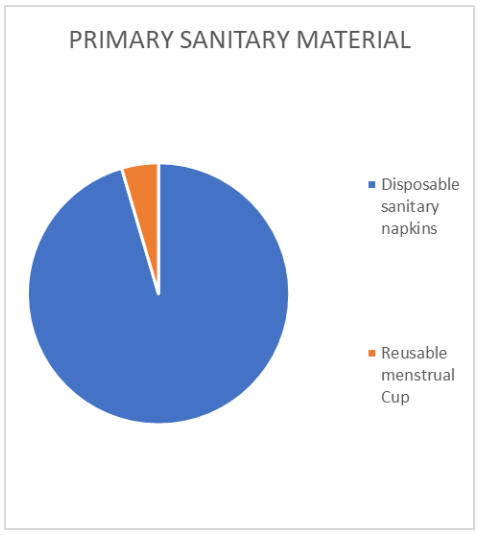

Figure 19 Primary sanitary material used

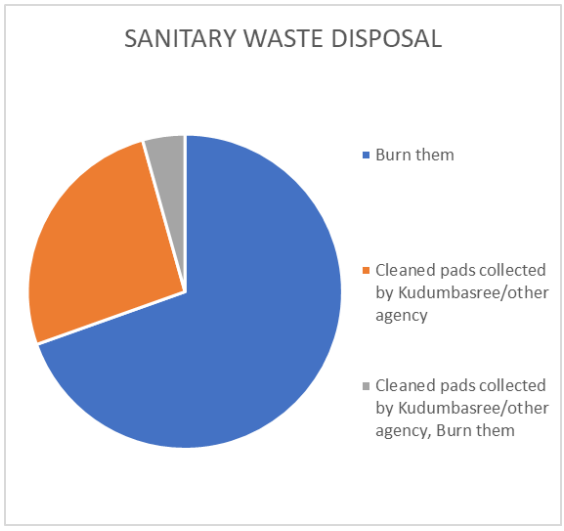

Figure 20 Sanitary waste disposal

The rating of cleanliness of the surroundings received two scores, average and good. Majority of the respondents commented that the cleanliness is average while others commented well on the cleanliness of their locality. We could infer that the management of solid waste in the locality was satisfactory or good.

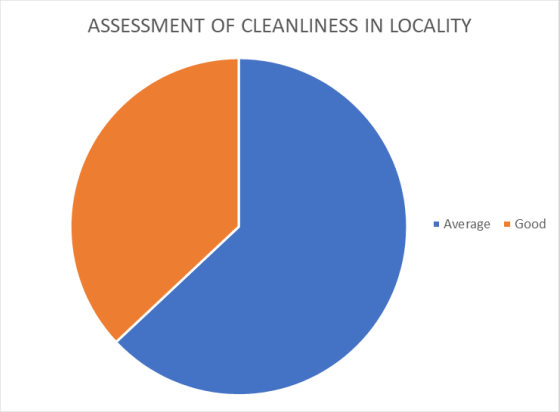

Figure 21 Assessment of cleanliness

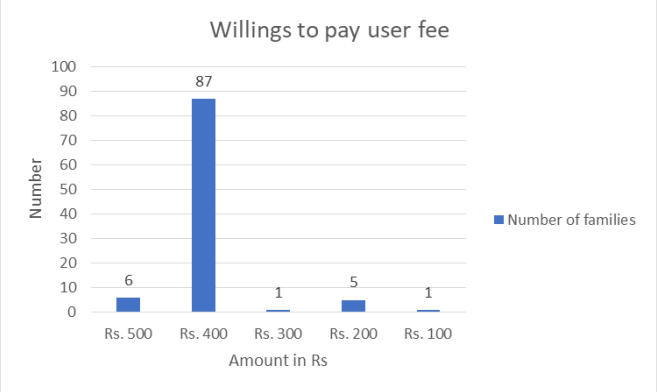

Figure 22 Willingness to pay user fee

Another welcome sign noticed is that every family surveyed was willing to pay user fee for availing waste collection services. 87% of the families are willing to pay Rs. 400 for the services, which is Rs. 100 in excess of what is paid as user fee now. Another 6% is willing to pay Rs. 500 per month for waste collection services.

4.4 Opinion Survey among HKS Workers

Haritha Karma Sena, a professional team of Green Technicians and Green Supervisors mainly Kudumbashree Women who are assigned with the responsibility of collection, transportation, processing, recycling / disposal, and management of waste materials in association with respective LSGs and Suchithwa Mission. Green Technicians are trained man power recruited to provide technical services and solutions on waste management projects. Haritha Sahaya Sthapanams are accredited agencies of Haritha Kerala Mission which provide technical assistance to the Haritha Karma Sena (https://kudumbashree.org/pages/676).

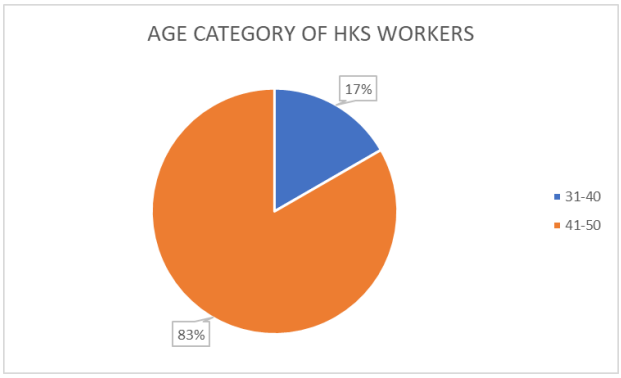

Figure 23 Age category of HKS workers

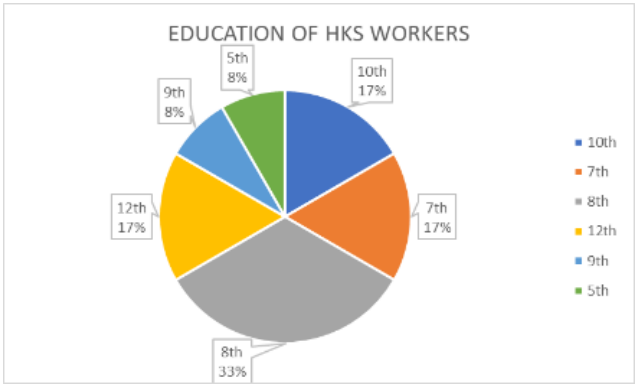

Figure 24 Education level of HKS workers

Majority of the HKS workers are aged between 41 and 50. The range of age of HKS workers ranges between 31 and 50. Majority of the workers are Hindu while small number follow Christianity and Islam. Out of the revealed data majority belongs to Scheduled Caste.

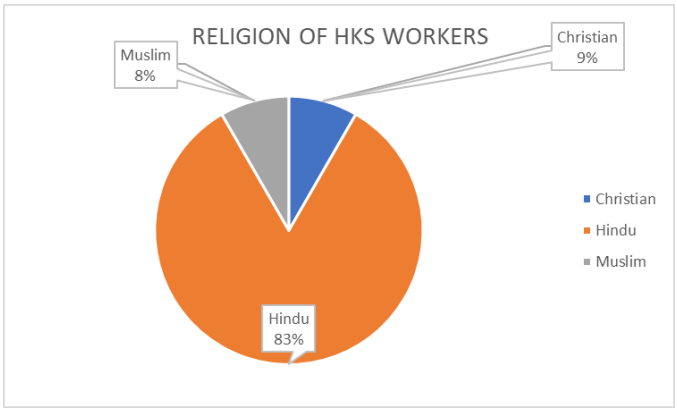

Figure 25 Religion of HKS workers

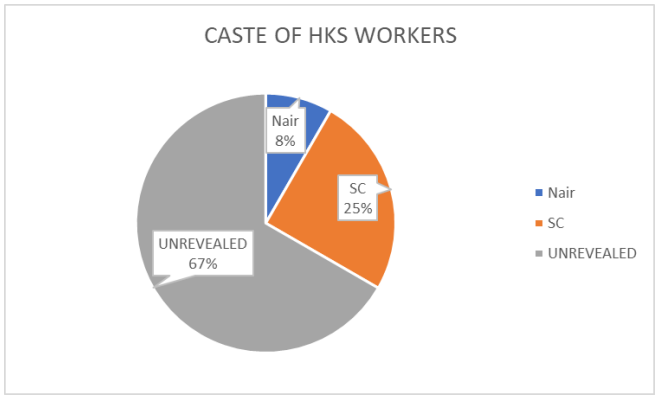

Figure 26 Caste of HKS workers

Education level of HKS workers in the study area ranges from 5th to 12th standard. Half of the population is temporary staff while the other half is permanent. There is employment security for half of the sample population. All HKS workers in the study area are married out of which 25% are widows. This figure is of an alarming proportion as the HKS are in the 31 to 50 age group. Family member strength ranges from 1 to 7 among the Haritha Karma Sena workers.

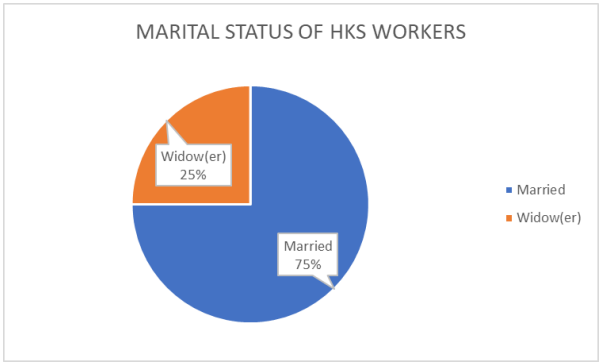

Figure 27 Marital status of HKS workers

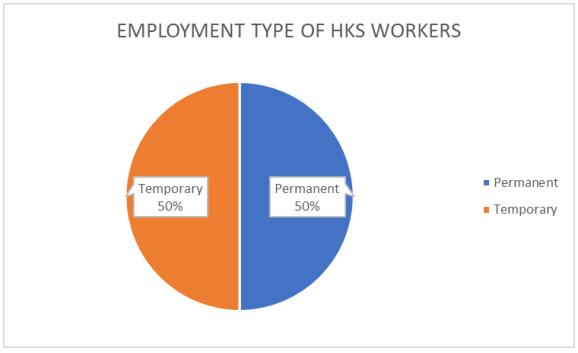

Figure 28 Employment type of HKS workers

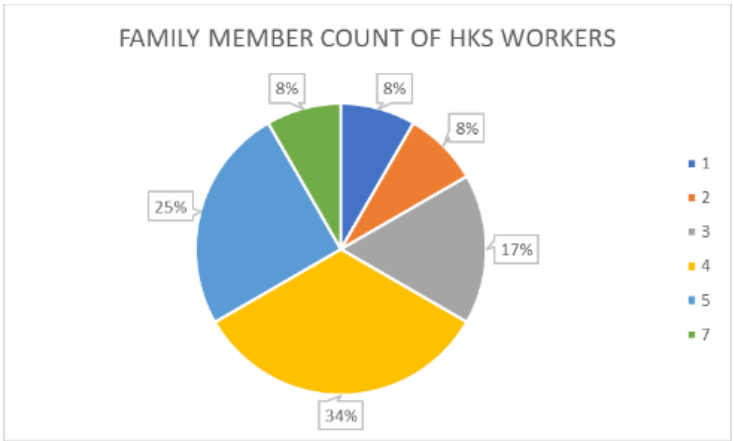

Figure 29 Number of members per family of HKS workers

4.5 Key Findings

Important observations came out of the study can be listed as below:

1. Waste segregation and source level composting is done primarily by women or jointly.
2. Willingness to pay for services received.
3. Willingness to participate in the waste management system of the city corporation
4. Willingness to adopt source level composting and biogas plants.
5. Receiving waste of neighbours to run the biogas plant.
6. Segregation of waste into 2 bins, 3 bins and multiple bins
7. Availability of parcels of land above 2 cents

All these aspects reflect the sustainability of the present waste management system practised in the ward.

4.6 Mode of operation of SWM in Kamaleswaram ward

The current system of waste collection, transportation, and treatment in Kamaleswaram includes some steps as listed below.

4.6.1 First collection

The solid waste generated in Thiruvananthapuram Municipal Corporation are collected by several agencies. The methods that are mainly used for collecting waste from the study area (Kamalaeswaram ward) use manual collection by waste collection crew (Haritha Karma Sena) from households and commercial establishments. From residents Haritha Karma Sena members (total 13 numbers) collects bio degradable waste daily and non- biodegradable waste weekly. From residential areas, after collection of food waste the crew carries the waste in buckets to a common storage point. Wet waste collection is implemented once per day in the morning, and street-sweepers clean the major streets every day. Households keep the waste segregated as wet organic and recyclable waste. All the plastic waste are washed, cleaned and dried before handing over to the collection crew. The direct truck collection includes the collection of wet waste by agencies directly from hotels and restaurants and taken to pig farms.

4.6.2 Transfer points in the streets

Food waste collected by Haritha Karma Sena is kept in roadside transfer points which in turn are collected and transported to pig farms by designated agencies.

Plastic waste and other recyclable waste are collected once in a week and also kept at designated storage points on the streets. The container systems are put in front of the hotels, offices, shops, etc. for containing the waste placed by the shops. After that, these wastes are collected and transported by Haritha Karma Sena and kept along with the household recyclable waste.

All the collected waste will be placed at various vacant areas on sidewalks/pavements. An initial segregation of recyclable waste is done on the ground at temporary transfer points, where the waste will remain until it is collected by a truck and is then further transported to the Material Collection Facility and then to Material Recovery Facility (MRF). This state will lead to substantial environmental problems at the transfer points. Therefore, there is a high demand for well-planned and accurately designed, well-constructed transfer points at suitable locations to put the pushcarts and containers, and empty and clean them from excess solid waste more efficiently.

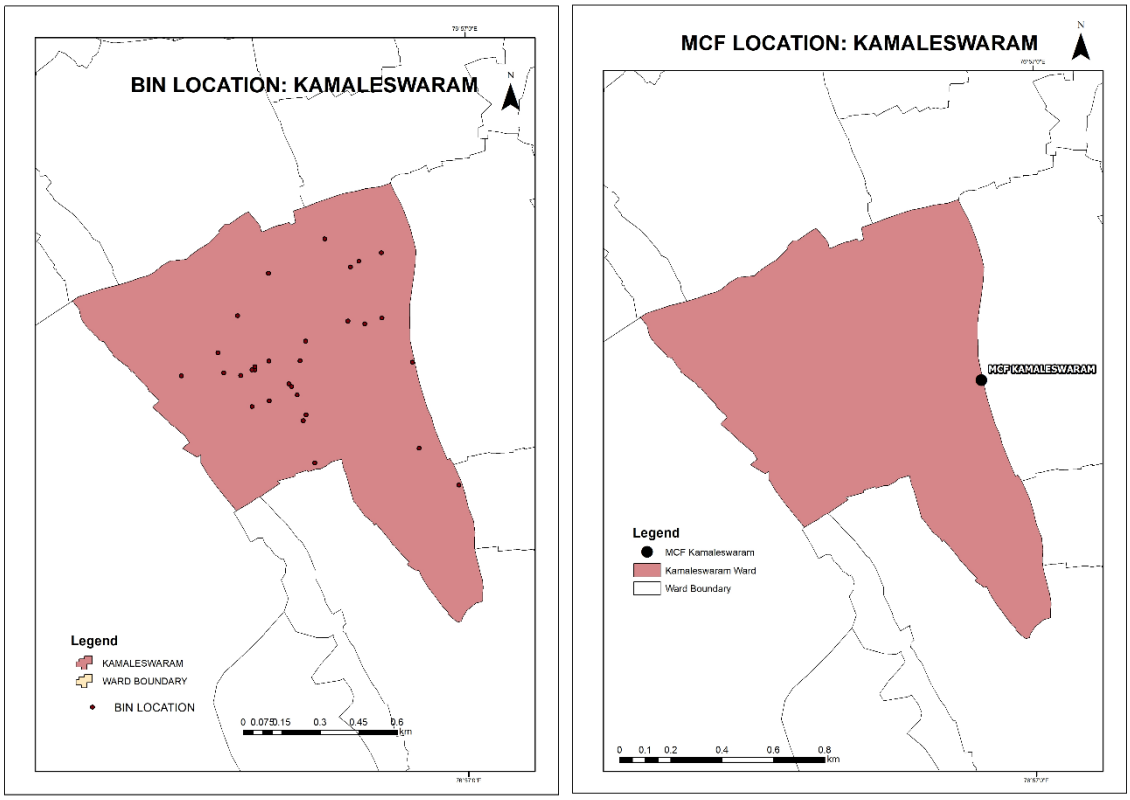

Figure 30 Transfer points and MCF Location - Kamaleswaram

4.6.3 Secondary collection

From the transfer points the wet waste/ food waste is collected and transported by designated agencies that had entered into contract with TMC to collect and transport waste. The agency entrusted to collect the bio waste from the study area transport the waste daily from the transfer points to the pig farms in Tamil Nadu.

While, the non-bio degradable waste after initial segregation is collected by designated agencies and transported to, suburb of TMC for sorting. Non-biodegradable wastes are collected from the collection points and are transported to MRF (Material Recovery Facility) at Punchakari for sorting. The sorted non-biodegradables are classified into recyclables and non-recyclables. Non-recyclable plastics of low thickness are shredded and used along with bitumen during road tarring. The remaining non-recyclable plastic is sent to cement plants in Tamil Nadu for use in Kilins. The recyclables are given for reprocessing through recycling to produce new products.

4.6.4 Recycling

About 10% of the municipal solid waste in the ward is expected to be recycled. The private and informal sectors implement most of the recycling activities. The recyclable materials and packaging waste are collected and handled in the informal sector and only a portion before it enters the formal collection channel. Some elements are separated at source, and some other fractions are processed by workers during collection and transportation. These collectors will separate, bale, and sell waste to the processing industry. The processing of recyclable waste, to a large extent, is carried out without any observation of operating practices. These activities pollute the air, water, and land substantially and seriously affect the health of those workers working in these areas.

5. DISCUSSION

5.1 General observations

Primary data obtained through the survey revealed many interesting facts regarding the management/disposal of biodegradable waste. Most of the households utilizes the door-to-door collection facility of Haritha Karma Sena for the disposal of both biodegradable and dry waste paying use charges. A number of households have installed portable biogas plants making use of the subsidy from the municipal corporation. Few residents receive wastes of their neighbours since the waste generated in their houses is not sufficient to run the biogas plant. This shows that the residents are moving towards a greener, economical and efficient mode of utilising the waste not only of their own but their neighbours as well, which points to responsible citizen's attitude. The residents are satisfied by the waste collection facility offered by the ULB though Haritha Karma Sena. Other mode of disposal used are pipe composts and kitchen bins. Some households keep pets like chicks, dogs, cats and cows and feed them with the generated waste to a great extent.

Being mostly nuclear families, the installation of biogas plant for individual houses is not a feasible option due to non-availability of sufficient waste to run the biogas plant to extract methane and hence the untapped gas is released into the atmosphere a cause of concern for greenhouse gas emission. Community-based installation of biogas plant and the generation of power or BioCNG may be beneficial and an option to be pursued. Installation of kitchen bin is an attractive option for nuclear families with less number of people but the data collected show less takers for the device. Elderly people may find it difficult to manage such processes but with a small assistance it may be beneficial.

While visiting the MCFs it was understood that Thumboormuzhi model aerobic bins are not functioning in the ward and hence closed down. An MCF with 3 Aerobic bins in Kamaleswaram boy's higher secondary school is closed down due to ill-functioning.

Figure 31 MCF at Kamaleswaram Boys Higher Secondary school

Figure 32 Community Level Composting plant at Kamaleswaram

The Haritha Karma Sena collects non-biodegradable waste from houses and establishments to shredding units for recycling. The waste is segregated into different fractions based on its features. H.M White, P.P, H.M, LD Print, Bajar, Gunny, Bulb, PVC, steel, tubes, bottle, E- waste, LD (Glucose), Bottle caps, Spray bottle etc. According to the mission, the shredded plastic is being given to the local bodies for road tarring by Clean Kerala Company. Each Kudumbashree worker will

visit minimum 250 houses to collect non-biodegradable waste. The collection will be based on user fee. The manufacture of environment-friendly materials, maintenance of waste disposal mechanism, organic farming, environment-friendly equipment on rent and compost making and associated works will be taken up by Haritha Karma Sena members.

5.2 Efficacy and Sustainability

Thiruvananthapuram Corporation is one of the most active municipalities maintaining cleanliness. Kamaleswaram ward is situated 2 km away from Eastfort towards Kovalam Beach, the landmark of Thiruvananthapuram. The adjacent ward, Manacaud houses Attukal temple which attract pilgrims on the occation of Pongala festival. A floating population of over a million gathers every year. Construction of new houses imply that population is yet to rise. The waste management system needs to be improved. Current scenario shows that 90% percent of the population is benefiting the service of Haritha Karma Sena who collects waste- both wet and dry- from the households to store at the allotted roadside locations. Bins are provided for wet waste and plastic sacks are provided for dry waste. Two bin and three bin segregation are found in most houses. Though some dry waste is mixed with wet waste. Like parcel packets from restaurants go straight to dry waste. Soiled Tissue Paper or Newspaper goes into wet waste. This forces HKS workers who need to (store them separately) sort the wet waste and dry waste at collection points.

As the wet waste is the food of pigs, they need to be free of hair, nails, paper and other indigestible materials. Daily collection van comes to pick the wet waste and weekly dry wastes are removed.

Only a third of the sample are using decentralised mode of wet waste disposal. The main reasons being lack of space, insufficient generation of waste and difficulty in maintaining the system.

Gloves are provided to all HKS workers along with uniform. Some of the workers whose gloves were torn found to be using plastic cover over their gloves, suggesting replacement of the same.

The TMC has established many infrastructural facilities for the management of MSWM through a decentralized approach in its different wards. The Thumboormuzhi model biodegradable waste treatment facility established in the Kamaleswaram ward is not functioning, similarly no dedicated MCF/ RRF for the ward. It uses the facility available in the nearby ward. For the recyclable plastics and paper the services of a private player is made useoff successfully. For the disposal of the biodegradable waste collected again the services of private player is sought who uses it as a successful venture as food in his pig farms in the nearby state.

The strong institutional mechanism of TMC combining elected representatives, TMC officials, volunteers, HKS and private entities for its MSWM is a successful model. HKS and private entities are facilitating door-to door collection, treatment, and transport and disposal services. This institutional mechanism of TMC for MSWM is operative in the Kmaleswaram ward also.

Looking at the economics of MSWM in the case of Kamleswaram ward and of the TMC, decentralization has proved to be economically viable when compared to the centralized approach which was followed previously. Large savings is achieved as can be seen in transportation cost of waste to the to the centralized plant, operational cost of the centralized facility, less carbon footprint as less truck movement etc.

The success of implementing a comprehensive joint awareness and action plan by TMC for adopting a community based decentralized approach in MSWM which started in November 2015 is reflected in Kamaleswaram ward. The main strategy of this program was a “segregated source level solid waste management” at household level; where the biodegradable waste will be composted at source and the non-biodegradable waste will be segregated at source and transferred for recycling. Unlike previous initiatives, this program was more participatory and has integrated the concept of ethics, economics and efficiency for MSWM without concentrating only on adoption of modern technologies.

The present study points to the fact that progressive changes in the behavioural patterns of the residents and increase in the efficiency of household management of biodegradable waste, source segregation of recyclable waste and paying user fees. A study conducted in the year 2003 reported that none of the houses in TMC limit was practicing source level segregation of waste (CED, 2003).

The progress made by TMC since the closure of its centralized MSW treatment plant at Vilappilsala is reflected in the MSWM in the case of Kamaleswaram ward. The progress in installing of household composting devices, giving subsidies, setting up of community aerobic composting facilities, source level segregation of waste, to setting up of material recovery facilities and deploying HKS for collection and transport of recyclables.

A few gaps in its implementation of decentralised approach in MSWM is came to front. The ward does not have any mechanism for collection and treatment of infrastructure within its limit for efficient management of sanitary wastes such as sanitary napkins and diapers. It is also seen that there is spatial disparity between the wards in the case of MSWM services obtained. As observed from the study Kamaleswram ward is using the facilities of nearby ward for its MCF/RRF requirements. Therefore, it can be assumed that the effective implementation of decentralization in MSWM have not reached all the wards of TMC. The capacity to handle the generated inorganic waste is doubtful, as the ward does not have effective infrastructure for plastic shredding and depends on the private player. This is also true in the case of TMC as well. A major proportion of the plastic waste is transported to Tamil Nadu for recycling, because the TMC does not have appropriate facility for its management.

Similarly, in the case of sanitary waste and household biomedical waste there is no effective mechanism in place for the proper management. The households resort to burning or illegal dumping as they have no other choice. The drainage network in the ward constitute Kariyal Thodu and a canal (Fig. 33).

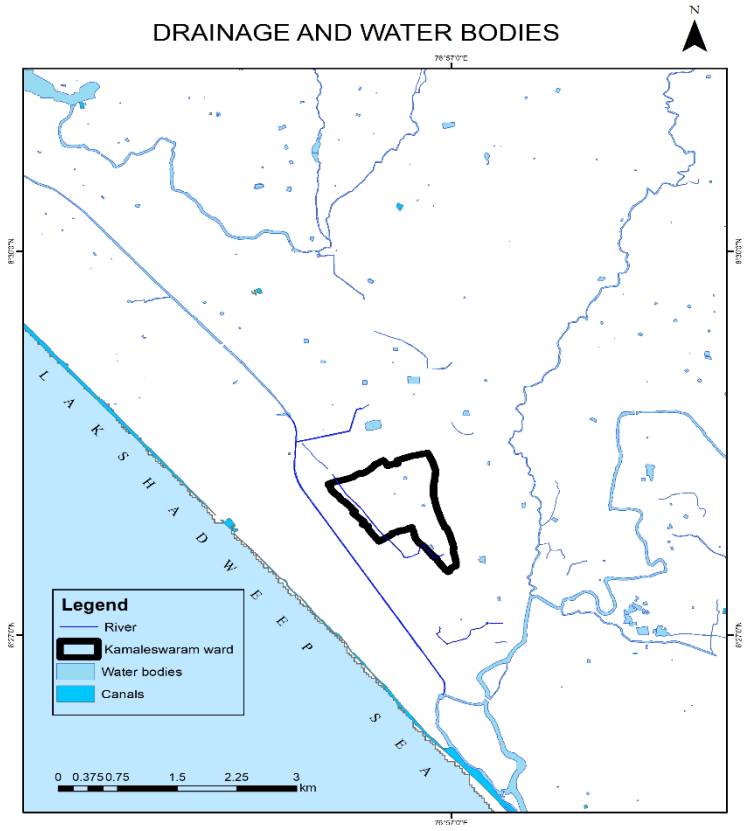

Figure 33 Drainage (Kariyal Thodu) and WaterBodies

The sanitary waste along with other wastes may reach the water bodies – Kariyal Thodu and pollute them. The probability of the waste getting transported from other wards are also possible to flow through this waterbody and get dumped. Seeking options of managing such kind of wastes at source pose higher amount of risk, as it needs sophisticated infrastructure and more skilled personnel.

Figure 34 Kariyal Thodu – Clear stretch

Figure 35 Kariyal Thodu – Waste Dump Stretch

6. CONCLUSIONS AND WAY FORWARD

A close examination of the case of Kamaleswarm ward and hence of TMC in the decentralized approach to MSWM it is evident that a mix of MSWM approaches is needed for the sustainable and effective management of MSW. Adoption of a decentralized approach as priority and implementation of a centralized approach for the management of recyclables and specific types of waste, such as sanitary waste, and household bio-medical waste could provide sustainability. The component of source level segregation which is the key for the success of decentralised approach will also form the decisive factor in the success of centralized MSWM and the circular economy based waste management principle also.

The approaches of decentralized MSWM and centralized MSWM can be integrated to form an

“Integrated solid waste management” approach for the city corporation. Integrated solid waste management is based on four basic principles: equity, effectiveness, efficiency and sustainability. Equity: all the people should be given access to suitable waste management model, considering the environmental and health reasons. Effectiveness: the chosen waste management model should lead to safe removal of all sorts of waste. Efficiency: the waste management model should be devised in such a way that the benefit from it is at an optimal level, while the incurred cost must be minimal. Sustainability: the waste management system should be adapted to the local conditions and should be a practical in terms of technical, environmental, social, economic, financial, institutional and political perspective. It should also be a sustainable in terms of its existence, without depriving the resources in which it exists (Klundert and Anschutz, 2001).

A plan for the effective implementation the current decentralized approach and a centralized approach should be developed, where the roles of the municipal body and the entire stakeholders associated with MSWM should be clearly defined. Implementation of such a plan will definitely resolve the gaps in the present waste management approach and will ensure equity, effectiveness, efficacy and sustainability.

As the major proportion of the plastic waste is transported to Tamil Nadu for recycling, the revenue for circular economy and the valorization opportunity goes to the next state. If more technologies and opportunities can be created for small and large scale entrepreneurship in the waste management sector, the revenue thereby, the circular economy can be retained for Kerala.

7. BIBLIOGRAPHY

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8. ANNEXURE 1 – Household

Household survey form

1. Name of owner
2. Location of house
3. Types of waste generated
4. How the waste materials are stored before collection
5. How the materials are sold to shops – either directly/through scrap workers
6. Price to which the materials are sold
7. How often the workers came to collect the waste materials
8. Do you segregate waste into wet and dry
9. How do you manage your food waste
10. What are the kinds of plastic waste generated
11. How much you pay as services charger/user fee for waste management monthly
12. Is the SWM in the municipality effective
13. If a more effective solid waste service is provided by the Municipal corporation, are you ready to pay for it in the form of user fee

9. ANNEXURE II – Haritha Karma Sena Survey

HarithaKarma Sena survey form

1. Name of the member
2. Type of house
3. Name of family owner
4. Location of the house
5. Total number of family members
6. Source of waste collection
7. Types of waste and price of their collection
8. Details of the industries to which the waste materials are sold
9. The approximate price received for each type of waste sold

10. ANNEXURE III – Haritha Karma Sena Job Satisfaction Survey

Jobsatisfaction survey form

1. Name of the industry
2. Name of owner
3. Location of the industry
4. The types of waste materials collected
5. Total number of employees
6. The areas/sectors from which the waste materials are collected
7. The approximate price for which the waste materials are collected
8. About MRF/MCF
9. Amount and type of waste that can be recovered/recycled
10. About the segregation and recycling processes and its methodology
11. Peculiarity of each waste collected and to which extent its recovers is possible
12. About the different processes taking place in this industry
13. The amount of waste material recovered
14. Type of materials gone as waste itself
15. Demand for raw material in the market
16. How the value of waste material changes after each process
17. To which all manufacturing industries the raw materials are sold
18. Which material is in great demand
19. Prices to which the materials are sold
20. How long is the job
21. To what extend is the job satisfied