Comparison of Material Flow Analysis in Kannur and Kozhikode Corporation and Proposing Methods for Treating Untreated Waste

Akshay Mohan, Muhammad Fayis.T

Abstract— with rapid growth of urban population waste management becomes a major crisis faced in most of our cities. Municipal solid waste (MSW) is an inevitable by-product of our actions. It is a mixture of various solid wastes by towns and cities from different type of activities. Integrated Solid Waste Management (ISWM) is an all-inclusive move towards prevention, recycling, and efficient waste management. ISWM establish equilibrium between the three dimensions of waste management: the efficiency of environmental protection, social acceptability, and economic acceptability. To solve out the waste management issues in a locality, proper understanding of the flow of goods through the existing system is inevitable. It gives a clearer portrait of the appropriate involvement strategies to be adopted. In the case of waste management, the graphical representation of a properly carried out MFA shows the flow of waste materials, products formed, and the emissions in a visually comprehensible and translucent way. In short MFA allows for a thorough assessment of the existing/proposed WMS so that the decision making can be done to solve out the main issues and support in attaining the overall goals of the ISWM plan.The graphical representation can be done by using software called STAN. STAN is freely available software that supports Material/Substance Flow Analysis (MFA/SFA) under the consideration of data uncertainties. It is capable of performing nonlinear data reconciliation based on the conventional weighted leastsquares minimization approach, and error propagation.

Keywords— Comingled waste, ISWM-Integrated solid waste management, MFA-Material flow Analysis, MSW-Muncipal solid Waste, SFA-Substance flow Analysis, STAN, WMS-Waste Management System

1 INTRODUCTION

With rapid growth of urban population waste management becomes a major crisis faced in most of our cities. Progress in almost every sectors of the society constantly occurs in a developing country like India. In compliance to the population explosion, improved rate of development activities, the quantum of waste generated is also rising up. This dynamics of transformation is particularly delicate in developing country. It is more reflected in urban area which is subjected to drastic changes in the socio-economical conditions. Even in a developed country, there are a number of constraints and limitations in executing a proper waste management plan. Improper implementation of the waste management system followed, lack of financial planning, and limited participation of locals are the main issues to be dealt with. It should also be noted that there are not many foolproof waste management systems available. The Sustainable Development Goals (SDGs) cannot be met unless waste management is addressed as a priority[3] **.** Municipal solid waste (MSW) is an inevitable by-product of our actions. It is a mixture of various solid wastes by town and cities from different type of activities. It can contain biodegradable waste, electrical and electronic waste, and composite waste such as clothing, hazardous waste and medical waste.

Municipal solid waste (MSW) management can be treated as the organized control of the generation, collection, storage, transport, source separation, treatment, recovery, and disposal of solid waste. As reported by Makarichi, WMS is generally considered unsustainable when final sinks (landfills) contain the bulk of the MSW throughout (which leads to rapid depletion of landfill space or excessive emission of landfill gases) or when toxic elements are accumulating in an intermediate or final sink at a rate higher than they are depleted, leading to the creation of highly contaminated environments which are often difficult to rehabilitate. Integrated Solid Waste Management (ISWM) is an all-inclusive move towards prevention, recycling, and efficient waste management. ISWM establish equilibrium between the three dimensions of waste management: the efficiency of environmental protection, social acceptability, and economic acceptability[5].

Even though the concepts of ISWM are familiar to us, still majority of our cities faces the ever increasing challenges put forth by MSWM. The way out to the waste management problem will be effective only when it is treated at the root of the problem. The figure below shows the seven step approach for developing a MSWM plan provided by the Municipal Solid Waste Management Manual published by CPHEEO, 2016.

- *Akshay mohan is currently pursuing masters degree program in environmental engineering at MDIT ulliyeri ,Kozhikodee,Kerala under Kerala Technical University, India, PH-9746277782. E-mail: mohan.akshay123@gmail.com*
- *Muhammad Fayis.T,Assistant Proffessor,Civil Engineering department, MDIT ulliyeri,Kozhikode,Kerala,under kerala Technical University, India, PH-9048404898. E-mail: fayis@mdit.ac.in*

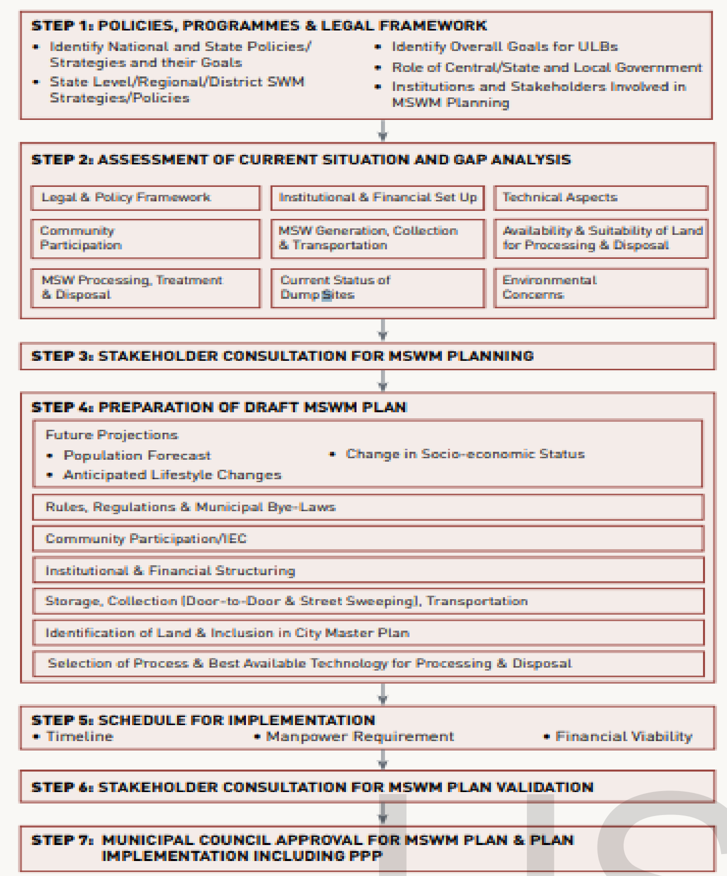

Fig. 1 Seven step approach for developing a MSWM plan

The most critical step in implementing ISWM is the assessment of current situation and gap analysis.. But the municipal authorities fail to carry out a critical assessment on the aspects of waste quantification and characterization..Hence it can be concluded that successful waste management cannot be achieved devoid of a comprehensive understanding of the material flows within a waste management system. A variety of analytical tools and methods are used to help the decision-making process in waste management. Analytical methods used in the waste management system can be classified into two groups:[5].

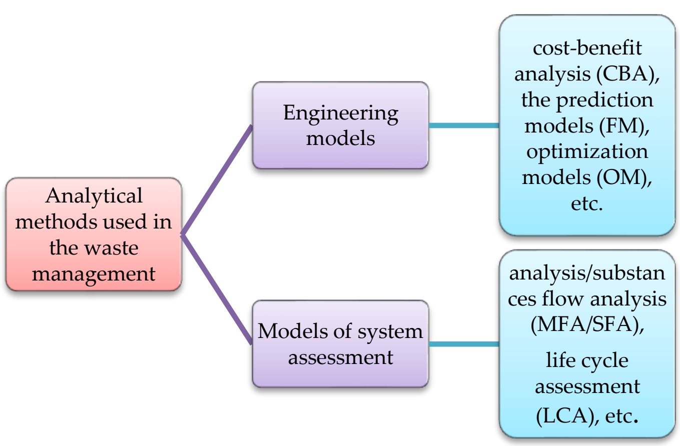

Fig. 2 Analytical Method Used in Waste Mnangement System

MFA is a systematic assessment of the flows and stocks of materials within a system defined in space and time[2].MFA is defined by two factors;

i. System boundaries in space and time

ii. Material flow entering, leaving, and taking place within the system.

It is based on the principle of mass conservation derived from the first law of thermodynamics. After assigning a system boundary on a spatial and time range, the total sum of mass of inputs must be equal to the sum of all outputs and the stocks within the system, as shown in equation 1[2]

$$\sum_{ki} \dot{m}(input) \;=\; \sum_{k0} \dot{m}\;(output) +\; m\,(s\dot{t}ock)\ldots\ldots\ldots\ldots\ldots\ldots Eq\ (1)$$

Application of this analytical tool in waste management planning is discussed in section1.2

1.1 The importance of MFA for waste management

As mentioned in the previous section, in order to solve out the waste management issues in a locality, proper understanding of the flow of goods through the existing system is inevitable. It gives a clearer portrait of the appropriate involvement strategies to be adopted. In the case of waste management, the graphical representation of a properly carried out MFA shows the flow of waste materials, products formed, and the emissions in a visually comprehensible and translucent way. In short MFA allows for a thorough assessment of the existing/proposed WMS so that the decision making can be done to solve out the main issues and support in attaining the overall goals of the ISWM plan.

MFA can be applied in any range of space and time. It can be used for assessing the performance of a single treatment process within a day to the performance assessment of a nation within a year. The results from MFA can be used;

i. As database of waste management development
ii. As a reference for decision making
iii. To analyze the possibilities of waste reduction
iv. To find out the possibility to reduce, reuse, and recycling waste
v. The results from various localities can be compared, to identify concealed problems.

As mentioned by Tang and Brunner [9] , the strategies can be formulated more effectively when the analysis is carried out at the level of the whole waste management system of a locality or a municipality. If changes made at a particular stage may well improve the efficiency at that level, it can also cause negative impact on overall efficiency. On a holistic approach when such negatives outweighs, the proposed plan can be considered to be ineffective. But MFA offers a system approach that helps decision makers to devise strategies that can optimise the overall efficiency of goal oriented waste management system. The application of mass balance principle ensures that all flows are taken into consideration, and no residues are omitted, making it trouble-free to spot out losses. The balances include detailed information regarding the management of goods and substances. (Table 1).

TABLE 1
DIFFERENT CATEGORY OF MFA AND THEIR INFORMATION CONTENT

Balance of goods	Balance of energy	Balance of pollutants	Balance of raw materials
Waste Production	Energy production and consumption	Emissions of pollutants in atmosphere and hydrosphere	Depletion of raw materials
Waste import and export	Energy recovery	Harmfulness of waste	Recycling rates
Potentials, limitations and starting points of measures for effective waste reduction	Potentials, limitations and starting points of measures for energy saving and recovery	Potentials, limitations and starting points of measures for effective reduction of pollution	Potentials, limitations and starting points of measures for effective protection of raw materials
		Identification of responsible goods	Potentials, limitations and starting points of measures for effective recycling. Identification of recyclable goods.

UN-Habitat has recognised the use of MFA as a process flow approach for implementing ISWM [9].

1.2 Application of STAN software for Material Flow Analysis.

MFA involves the representation of a system in graphical format. Manually developing the same will be tedious and time consumption, for a system like MSWM for a large municipality. Thus software named 'Software for Substance Flow Analysis' (STAN) software has been developed. It was developed by Oliver Cencic, Institute for Water Quality, Resource and Waste Management, Vienna in 2004 [7]. This software provides readymade graphical representations of flows, processes and system boundary as shapes .

After building a graphical model using the predefined components, the user can enter or import known data for different layers and periods to determine unidentified quantities. The flows within the system can be represented in Sankey style, (width of a flow is proportional to its value). The output can be printed or exported. For importing and exporting data Microsoft Excel can be used as an interface. Mcrosoft Excel can be used as an interface.

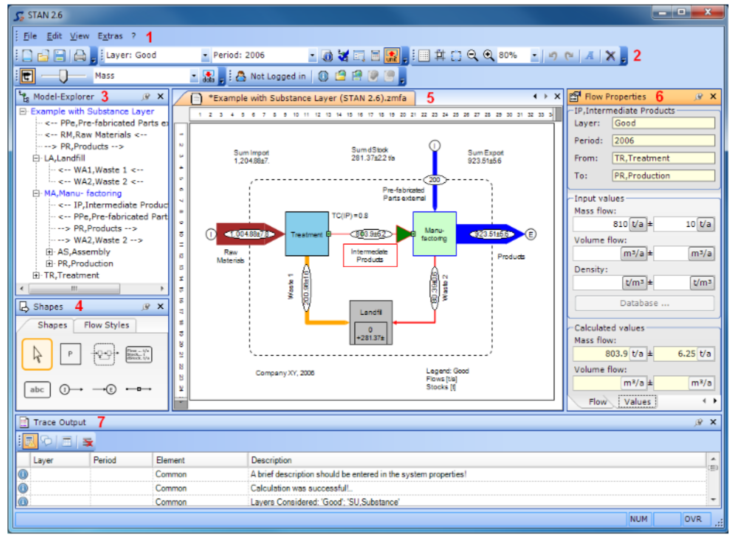

Fig. 3 Graphical user Interface of STAN Software

Fig 3 shows the graphical user interface of STAN software that is being used for the assessment of waste management.

1.3 Modelling of STAN

A number of processes and flows constitute the model of a system. A process is a place where transportation, conversion, or storage of materials takes place. Generally, processes are defined as black boxes, meaning that detailed information what is happening inside is not available or not taken into account. Only the inputs and outputs are of interest [9]. Different processes are connected to each other through flows, represented using arrows. Flows which cross the system boundary are called as import (I) or export (E) flows. Figure 4 shows an example model with the data;
1. Raw material is 100 tonnes/annum (t/a) (fixed value for this flow) and
2. Recycling rate is 70% (transfer coefficients that the recycling flow equals 0.7 of the product inflow).

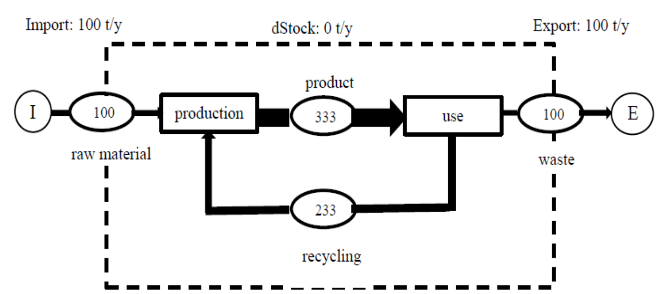

Fig. 4 A basic STAN Model

Based on the above data inputs, the unknown flows were calculated using STAN and the result is represented as Sankey. Due to the redundancy of a MFA system, sometimes STAN shows indications where to look for missing mass flows [9].

2 METHODOLOGY

The methodology chosen for carrying out the present MFA study consists of the following steps as shown below:

- Defining the objectives & purpose of the study
- Selection of study area/ the system
- System and process definition
- Defining materials for analysis
- Data collection
- Determining the limits of the system in time and space
- Conduct MFA using STAN software
- Balancing the inputs, outputs and stock through the processes.
- Results presentation and Interpretation of results
- Discuss how the gaps could be filled to strengthen the whole management system
- Proposing suggestion to reduce the untreated waste

2.1 Defining the objectives and purpose of the study

The purpose of present study is to assess the application of material flow analysis as a tool for comparing effective municipal solid waste management plans of Kozhikode and Kannur Corporation

The objective of this study is as listed below:

a. To evaluate current waste management system of Kozhi kode and Kannur Corporation in terms of waste processing efficiency

b. To identifying the gaps and limitations of existing solid waste management practices of the study area

c. To assess the application of MFA as a decision making tool for effective solid waste management

d. To propose an effective method for treating biodegradable waste at residential areas.

2.2 Identification of study area

The study area chosen for the present study is Kozhikode Municipal Corporation and Kannur Municipal Corporation. As fast developing cities this municipal corporation faces the problem of solid waste pollution.

2.3 System and process definition

The system definition, is the design process that models the system corresponding to the particular objectives. By means of the system definition a picture is created where a variety of processes and links (waste flows) as a simplified and manageable model stand for a highly complex reality. The model responds to the objectives of the study.

The system considered in the present study is the solid waste management system followed by the Kozhikode and Kannur municipal corporation area. Before adopting primary and secondary data collection, the following flowchart derived from the CSP toolkit is adopted to define the system

2.4 Defning materials/goods for analysis

In this methodical step, input and output goods are selected and characterized, and the links are identified. In the present study, municipal solid waste generated & processed within the Corporation limit is considered as the material for analysis.

Decisions on recycling, optimisation of waste treatment processes and predictions of emissions from waste treatment require information about the flow of goods in municipal solid waste. Hence, the waste generation rate and the contribution of each individual waste fraction to the total composition of municipal solid waste are of interest in this study.

2.5 Data Collection

The information on the current practices was collected from the Municipal Corporation Office, Health Inspector Offices and through reconnaissance surveys. Process wise information comprising collection, storage, transportation, processing and disposal was collected to understand the existing solid waste management systems. Based on the analysis of the secondary data collected, gaps and deficiencies in the present system were identified.

2.6 Determining the Limits of the System in Time and Space

Defining the system boundary is done after the data collection. The system boundary is drawn in both time and space, in dependence to the specific objectives of the study. The time component of the system boundary presents the base for the balance time range.

TABLE 2

EXAMPLES FOR SPATIAL SYSTEM BOUNDARY

Spatial system boundary	Examples
Real estate boundary of an enterprise	paper mill, hospital, waste incineration plant
Political boundary	city, community, province, nation, nature reserve
Boundary of a socially defined unit	private household

Examples on the spatial system boundary are shown in the table 2.

2.7 Conduct MFA using STAN software

In this study, the STAN model helps to visualise the whole solid waste and recycling system within the boundary of the project area. All solid wastes produced in the region are treated as system inputs, material flows are clearly shown along the system boundaries, and the system output forms the rejects and untreated waste.

2.8 Balancing the inputs, outputs and stock through the processes

The goal of MFA is to establish a mass balance for a system of study. The sum of all inputs into the system must equal all outputs plus changes in stock. Static models provide insight into investigated systems for a specific time. Therefore, they allow assessing current states of a system. In this study a static MFA for the year 2019 is carried out.

2.9 Results Presentation and Interpretation

Results presentation and Interpretation is performed in the following steps:

a. Results depiction by means of tables and graphs. Goods and substance flow diagrams, tables and graphs.

b. Assessment of achieving the purpose and objectives of the study

3 RESULT & DISCUSSION

3.1 Data collection

Datas where collected from Kozhikode Municipal Corporation and Kannur municipality. Existing data were collected from the sources such as:

1.Swach survekshan league 2020

2.Status report of Solid Waste Management in KMC 2019

3.City sanitation Plan 2018

4.City Report of Kozhikode 2018

3.2 Data collected from Kozhikode Muncipality

Various composition of municipal solid wastes in Kozhikode municipality is shown in table 3.

TABLE 3

COMPOSITION OF MSW IN KOZHIKODE MUNCIPALITY

Category	Net Weight in %
Bio-degradable	70 - 75(approximately)
Recyclable-Paper, plastic, metal, rubber, glass	15
Inert	10

The waste produced from households, shops and commercial establishments are composed of food and other discarded waste materials such as paper, plastic, glass, metal, rags, packaging materials. The waste is found to be rich in organic matter and contains about 83% compostable matter.

TABLE 4

SALIENT FEATURES OF SOLID WASTE MANAGEMENT IN KOZHIKODE MUNCIPALITY

Functional element	Data obtained
Waste generation	300 tons/day (TPD) at a per capita of 0.477 kg/capita
Segregation at source	30%
Storage at source	60%
Primary collection	54% households and 16% of non-domestic sources
Secondary storage	28 numbers open collection / direct transfer points and 8 dumper placer containers.
Transportation	Mixed vehicle fleet of tractors, tipper and dumper placers. On an average only 128 tons of waste is transported daily.
Processing	City level compost plant to process 100 tons/day. Method of composting-windrow composting
Disposal	Crude dumping of mixed waste in haphazard manner. No environmental controls.
Vehcles, tools, equiments	Box type carts (primary collection and street sweeping), Tractors with open/closed trailers, open trucks and closed mini trucks and dumper placers.

Percentages of waste managed in different stages are summerised as shown in table 4.

TABLE 5

PERCENTAGE CONTRIBUTION FROM MAJOR WASTE GENERATORS

Source of generation	Percentage of total waste generated (%)
Domestic sources	46.89
Commercial Establishments	13.19
Hotels & eateries	11.27
Hospitals (non infectious)	3.11
Other sources (Marriage and functional halls, street sweepings, schools and institutions)	25.54
Total	100

The percentage contribution of major waste generators is being mentionedin the table 5.

3.3 Data collected from Kannur Muncipality

Datas where collected from kannur municipality corporation expecially from the health department and solid waste management wing. Existing Percentages of waste managed in different stages are summerised as shown in table 6.

TABLE 6

SALIENT FEATURES OF SOLID WASTE MANAGEMENT IN KANNUR MUNCIPALITY

Functional element	Data obtained
Waste generation	110 tons/day(TPD) at a per capita of 0.477 kg/capita
Segregation at source	25%.
Storage at source	40%
Primary collection	44% households and 13% of non-domestic sources
Transportation	Mixed vehicle fleet of tractors, tipper and dumper placers. On an average only 68 tons of waste is transported daily.
Processing	City level compost plant to process 100 tons/day. Method of composting- Ring compost, Thumburmuzhi chamber
Disposal	Crude dumping of mixed waste in haphazard manner. No environmental controls.
Vehicles, tools, equipments	Box type carts (primary collection and street sweeping), Tractors with open/closed trailers, open trucks and closed mini trucks and dumper placers.

The waste generation is Kannur municipality is comparatively low when compared to Kozhikode municipality.

3.4 Modified process flow

Datas where collected feom kannur municipality corporateonBased on the data collected, the process flow was well defined as shown below. The formal system of solid waste management in Kozhikode Corporation mainly consists of collection and transportation of the city waste to a centralised compost plant or to a material recovery centre. Women who are the members of Kudumbasree (Women Self Help Groups) are engaged in waste collection from waste generation points. The workers organize door to door collection of the waste from households and shops; segregate and load it into vehicles which are then transported to primary collection points and then to secondary collection points. From these points it is directly transported to the windrow composting plant where it is processed and converted to manure. From some of the generation points the waste is directly collected and transported to the disposal site. The non biodegradable portion of the MSW is carried into a material recovery centre for recovery and plastic recycling

3.4.1 Efficiency of Existing SWM in Kozhikode Muncipality

The results obtained from STAN model are as follows. The efficiency is differentiated on the basis of source level treatment,Final compost from windrow compost plant,Recycled plastics,Materials Recovered,Rejects,Untreated waste.

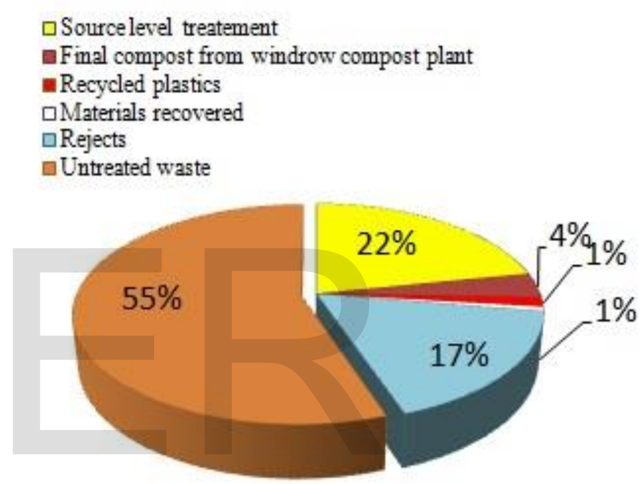

Fig. 5 Efficiency of existing SWM in Kozhikode municipality

The Efficiency shows that the untreated waste is 55%, Rejects are of 17%, Source level treatment of 22%, Recycled plastic of 1%, Final compost from windrow compost is 4% and the material recovered is 1%.

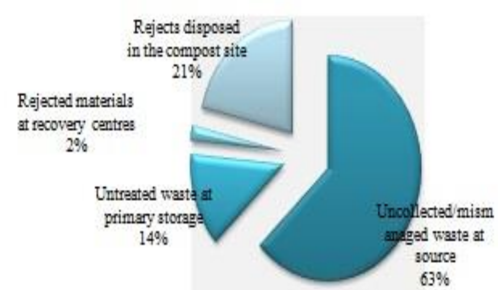

Fig. 6 Percentage contribution of uncollected/mismanaged MS

There are about 63% of uncontrolled waste at source level and 14% at primary storage. Uncontrolled wastes at composite site and recovery centres varies as 21% and 2% respectively.

3.4.2 Efficiency of existing SWM in Kannur Muncipality

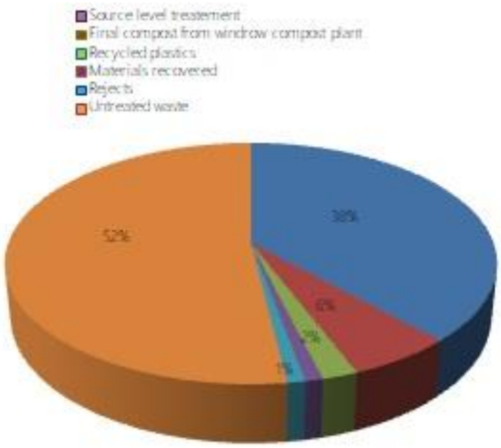

Fig. 7 Efficiency of existing SWM in Kannur municipality

The Efficiency shows that the untreated waste is 52%, Rejects are of 1%, Source level treatment of 32%, Recycled plastic of 1%,Final compost from windrow compost is 2% and the material recovered is 1%

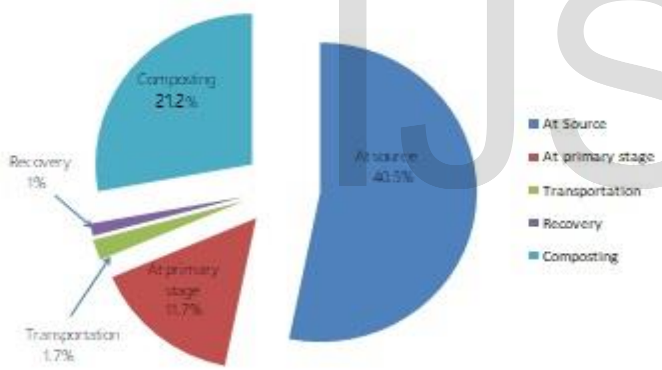

Fig. 8 Percentage contribution of uncollected/mismanaged MSW

4 COMPARISON OF SWM IN KANNUR AND KOZHIKODE MUNCIPALITY

The comparison of kannur and Kozhikode is done based on the uncollected and untreated waste obtained from each stage.

TABLE 7
COMPARISON CHART OF UNCOLLECTED/MISMANAGED WASTE IN KANNUR AND KOZHIKODE MUNCIPALITY

Uncollected/Mismanaged	Kozhikode	Kannur
At Source	63%	40.5%
At Primary storage	13%	11.7%
During Transportation	1%	1.7%
At Recovery centre	1%	1%
At Composting site	22%	21.2%

By comparing it is understood that the uncollected/mismanaged waste in kannur is compritively lesser than Kozhikode eventhough both the municipalities have unsatisfactory methods of waste management.

5 SUGGESTIONS TO REDUCE THE UNTREATED WASTE

1. Ensure Segregation at source
2. Encourage decentralised waste management
3. Practice community level composting
4. Establish more number of material recovery centers
5. Focu towards primary collection
6. Monitoring of existing composting plants
7. Need for training for personnals in SWM
8. Keep record and coordination of resources

6 CONCLUSION

There is an urgent need to streamline solid waste management systems in Kozhikode and Kannur Corporation. Ensuring segregation at source it reduce the existing problems connected to solid waste disposal to a considerable extent. Decentralising the waste management with appropriate technologies where ever possible is an imminent need.

Through this project, the current solid waste management system of Kozhikode Corporation was evaluated by applying material flow analysis. Based on the STAN modelling prepared, gaps and limitations of existing system was defined.

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