Waste Footprint of Kochi City, Kerala – An Analysis

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Abstract: Common waste produced during pre modern era was mainly ashes and human waste, and these were released back into the ground locally, with least environmental impact. Following the onset of industrialization and the sustained urban growth of large population centers, the buildup of waste in the cities caused a rapid deterioration in levels of sanitation and the general quality of urban life. A lot of solutions arose like land filling, composting, incineration, pyrolisis etc. for handling the problem. But all of these either had an environmental impact or a public protest. What we have to do is to have a proper account of waste generated and its impact. Waste foot printing is one such technique which quantifies the impact of waste generated by an individual. This paper gives an overview of the waste foot print of residential areas of Kochi city, its analysis, findings and discusses the various sustainable options to reduce the waste footprint of the residential areas of Kochi city.

Keywords: Urbanization, sustainable waste management, ecological footprint, waste footprint, Kochi city.

Introduction

Urbanization is the movement of people from rural to urban areas [1]. The urbanization trend nowadays and the modern life style have increased the waste load on the earth and thereby polluting the urban environment to uncontrollable and dreadful limits [2]. The existing land fill sites and waste dumping sites are full beyond capacity and under unhygienic conditions leading to pollution of water sources, proliferation of vectors of communicable diseases, foul smell and odors, release of toxic chemicals, unaesthetic feel and ambience etc [3]. In earlier days, municipal wastes, comprised mainly of biodegradable matter, did not create much problem to the community as the quantity of wastes generated was either recycled/reused directly as manure or was within the assimilative capacity of the local environment [4] . The biodegradable wastes of the urban centers were accepted by the suburban rural areas for bio composting in the agricultural areas. With increasing content of plastics and non-biodegradable packaging materials, municipal wastes became increasingly offensive to the farmers and cultivators. As a result, the excessive accumulation of solid wastes in the urban environment poses serious threat not only to the urban areas but also to the rural areas. Now, dealing with waste, is a major challenge in many of the local bodies or government. There are two aspects to the challenge, the social mind set and technology application [5]. The social mind set is a very important aspect to be considered in this challenge. People are having the notion that the government is the authority to dispose whatever waste they are generating. This is very pathetic situation. Only the generators can manage waste. Though there are campaigns and awareness programmes to reduce the waste generation and source reduction, it is very hard to maintain the enthusiasm after the campaigns. In these circumstances we have to think of an alternative which is to be enforced by laws or rewards to reduce the amount of waste generation. A system, which gives the waste impact on earth quantified, just as we take the current bill, water bill etc and an amount to be paid based on the quantity, should be imagined. Or on the other hand the waste generators which are causing low impact should be rewarded or appreciated. There should be clear cut limit for this quantified value based on the locality we live in and its biocapacity to assimilate the waste. Waste foot printing is one such tool which can reach these goals to some extent [5].

Kochi, the commercial capital of Kerala and the second most important city next to Mumbai on the Western coast of India, is a land having a wide variety of residential environments. Central city extends to an area of 275.85 sq.km and the area jurisdiction of the city corporation is 94.88sq.km [6]. The population of the corporation area as per 2001 Census is 5,95,575 and the gross density is about 6277 persons/sq.km. As per 2011 Census the population is 6, 01,574 [6]. From the ecological footprint studies in Kochi city, it is revealed that the consumption rate (EF=2.19gha) of the population in the city is very high and it is far exceeding the national average (0.8gha) and the nations biocapacity (0.4gha) and the available bio capacity per person in the world (1.8gha). The study also revealed that shelter footprint, which mainly depends on the house area usage and number of occupants, is very high in the city. The improper waste disposal at the source (residential units) is increasing the waste footprint of the population which results in the high goods and services footprint [6].

This paper gives a detailed analysis (general and statistical) of the waste footprint of Kochi city, findings and discusses the various sustainable options for reducing the waste footprint of the residential areas of Kochi city.

Concept of Waste Footprint

Before detailing the waste footprint concept, the concept of ecological footprint analysis [7] is briefed since waste footprint is a subset of ecological footprint. Ecological footprint analysis is a quantitative tool that represents the ecological load imposed on the earth by humans in spatial terms. Ecological footprint analysis was invented in 1992 by Dr. William Rees and Mathis Wackernagel at the University of British Columbia [8]. The ecological foot print of a defined population is the total area of land and water ecosystems required to produce the resources that the population consumes, and to assimilate the wastes that the population generates, wherever on earth the relevant land / water are located. The footprint is expressed in global hectares. A global hectare is one hectare of biologically productive space with world average productivity [9].

By the waste footprint or the ecological footprint of waste generation, the measurement of biologically productive land like fossil, energy land, forest land, pasture land, built up area etc, to assimilate the generated waste is meant [10]. Waste footprint can provide the per capita land requirements for waste generation. By calculating the waste footprint, the local authority can determine the land required assimilating the waste generated in present and future, selection of disposal site and disposal site characteristics, the land fill site design and the importance of recycling of different waste categories in order to reduce the footprint [10].

In calculating the ecological footprint for household waste generation, methodology to assess the household ecological footprint, developed by Mathis Wackernagel, Ritik Dholakia, Diana Deumling and Dick Richardson, Redefining Progress v 2.0, March 2000, was used. The methodology utilized the resource consumption and waste generation categories and the land use categories for those consumption and waste generation. [10]. The land use categories are summarized as

- Energy Land: The area of forest that would be required to absorb the CO_2 emissions resulting from that individual's energy consumption.
- Crop Land: The area of cropland required to produce the crops that the individual consumes.
- Pasture Land: The area of grazing land required to produce the necessary animal products.
- Forest Land: The area of forest required to produce the wood and paper.
- Sea Space: The area of sea required to produce the marine fish and seafood.
- Built Area: The area of land required to accommodate housing and infrastructure.

To calculate the ecological footprint of waste generation, the generated waste is categorized as paper, plastic, glass, metal, and organic waste (food waste). The sum of the total land required for different waste categories the biologically productive land required for waste assimilation can be obtained, which means the per capita ecological footprint of waste generation. The methodology presents all results in per capita figures. Multiplying the per capita data by the selected area's population gives the total waste footprint of that area.

Waste Footprint of Kochi City

Methodology

The city accommodates a population of 6,01,0574 as per 2011 census. For the detailed study of waste footprint of the city, representative samples were selected from the residential areas of the Kochi Corporation and outskirts. The samples were selected based on the following criteria

- density of population(high and low)
- location(away and near of CBD and major transportation nodes)
- mode of waste disposal(household level or community level)
- type of housing unit(individual plots, low rise building, row housing units high rise building)
- ownership of the building(individuals, government, builders)

The survey was conducted using a structured questionnaire containing questions concerning the socio economic profile of the households, quantity of waste generation of each category of waste, type of waste disposal etc. The objective of the questionnaire was to analyze the variation in waste footprint values depending on the socio economic profile of the people, quantity of waste generation, daily variations and the type of waste. Questionnaire survey was conducted for 500 samples during three different seasons namely dry season (April 2010 and December 2010-January 2011), wet season (July 2010) and festival season (August 2010), inside the Corporation boundary and random samples in the outskirts.

The year 2010 was taken as the base year. For tracking the waste generation and the recycling methods in the residences after the primary survey, survey was repeated in 7% of the primary survey samples in 2011, 2012 and 2013. The criteria for house selection in the second stage survey were the response from the inhabitants in the base year survey and level of cooperation. 15 enumerators participated in the base year survey. Households were requested to segregate the wastes generated per day and store for one day. The wastes generated from samples were categorized into paper, glass, plastic, metal and organic waste (mainly food waste). The amount of paper waste was indirectly taken from the data of periodicals in the houses. The amount of glass and metal waste generated in a week was taken in account.

Analysis of the Waste Foot Print of Kochi City

The analysis was done to find the yearly variation of waste with respect to the criteria selected during the survey. The analysis was done using the waste footprint analyzer which is a program developed based on the equations of ecological footprint of waste generation developed by William Rees and Mathis Wackernagel (1996), the authors of the concept for inputting the survey data and estimating the footprint values in a visual basic platform. The analyzer generated the footprint value in hectares per capita. Fig. 1 gives a display of the analyzer which communicates mainly through 3 windows.

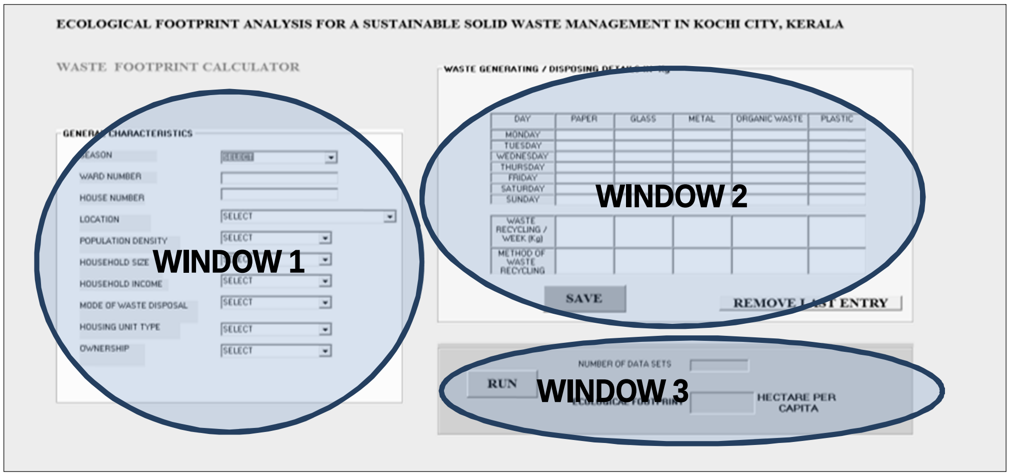

Figure 1. Windows/components of waste footprint analyzer

Window 1 and Window 2 are data input windows and Window 3 is execution cum output window. Window 1 has 10 sub windows which feeds the socio economic characteristics of the household under survey. The entries regarding season, ward number, house number, location, population density, household size, household income/month, mode of waste disposal, housing unit type and ownership details can be entered through these sub windows. Window 2 deals with the waste generation characteristics of the household. Window 3 is an execution cum output window. It consists of RUN button and a sub window. The button 'RUN' is an execution button which triggers the program execution. The sub window displays the number of datasets entered and gives the footprint value in hectares per capita.

The 500 samples' questionnaires in three different seasons were entered and the programme is executed to get the waste foot print of the residents of the city. 1500 datasets were created on this account for waste footprint calculations. The analyzer displayed the waste footprint in hectare per capita.

Statistical analysis and method

For combined analysis of the data over years in order to analyze the variations in quantity and footprint values in different conditions, homogeneity of error variance across all years were tested for significance by doing Bartlett's chi-square test (Gomez et al., 1984) for each variable. The test results showed that except for a very few cases the error variances were homogenous. Therefore the pooled analysis (Gomez et al., 1984) of variance could be conducted across the years to test if the variable was significant over the years and whether the interaction between year and the variable was significant. Since the sample size of each case was different, this was done by curtailing the sample size to the minimum size of the cases. The data was selected at random. The pooled analysis has been done in split plot manner.

Results and Findings

- The waste generation in the residential areas of Kochi City as on 2013 is 0.51kg/capita/day with an average household size of 3.72.
- On an average the organic waste constitutes 80.1%, 10.5% metal waste, 5.1% glass waste, 2.6 % paper waste and 1.9% plastic waste.
- In order to assimilate these wastes an area of 0.013 hectare per capita is required in the dry seasons, 0.016 hectare per capita for the festival seasons and 0.015 hectare per capita for the wet seasons.
- An average of 132.04 m^2 per capita of energy land, 0.08 m^2 per capita of forest land and 16.47 m^2 per capita of built up land is required to assimilate the waste generated by the residents of Kochi city.

- Even though the percentage of plastic in the solid waste is low compared to the other components, its percentage share of total waste footprint is relatively higher than other components except for metals. Metals also contribute to higher footprint. This is evident from the Fig. 2.

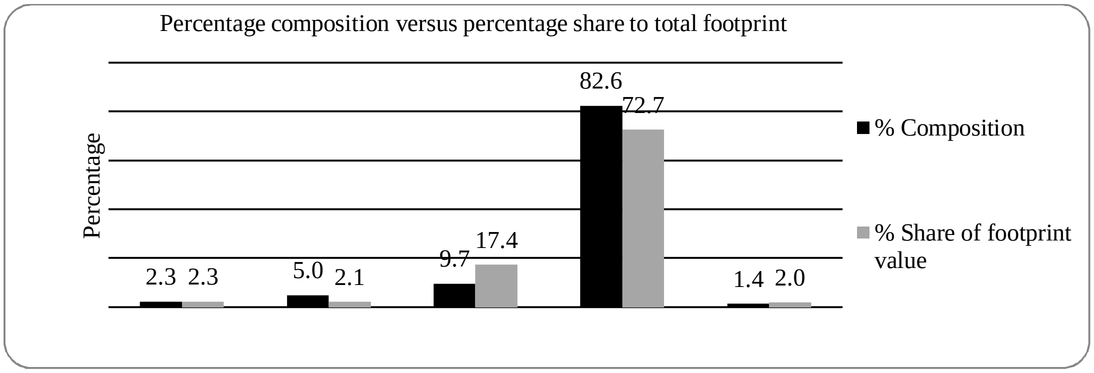

Figure 2. Percentage composition versus percentage share to total foot print

- The temporal variations of the waste footprint of the residential areas of Kochi city shows that the waste footprint has been increasing from 0.129 hectares per capita in 2010 to 0.0163 hectares per capita in 2013. This accounts for 26.35% increase within 4 years (Fig. 3).

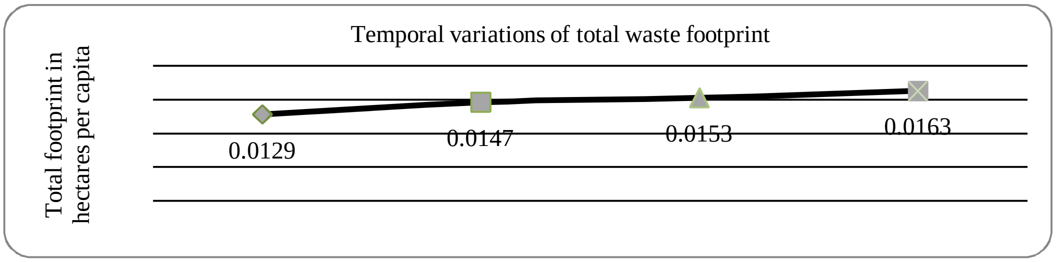

Figure 3. Temporal variations of waste footprint

- The analysis of ecological footprint of waste generation in the residential areas of Kochi city showed that with the present trend of waste generation and an assumed population growth rate of 4.5% as per the census studies, by 2051 the population will need about the full area of the city to assimilate the generated waste. This is shown in Table 3.

Table 3. Land requirement for waste management of the city

Year	Population	Waste footprint per person	Area (hectares) required for the total population
2001	595575	0.0129	7674.6
2011	601574	0.0129	7751.9
2021	628645	0.0129	8100.7
2031	656934	0.0129	8465.2
2041	686496	0.0129	8846.2
2051	**717388**	**0.0129**	**9244.3**
2061	749671	0.0129	9660.3
2071	783406	0.0129	10095.0
2081	818659	0.0129	10549.2

Paper waste

- On an average, the paper waste constitutes 2.6 % of total waste generated by the residents of Kochi city which includes magazines, newspapers, paper for packing, notices, information bulletins, paper items related to school, offices from the house.

- The average paper footprint of the residential areas of Kochi city is 4.06 m^2 per capita which implies that about 4.06 m^2 land area per person is required to assimilate the paper waste generated. This requires 3.53 m^2 of energy land, 0.08 m^2 of forest land and 0.44 m^2 of built up land.
- The paper waste constitutes maximum during the wet and festival season compared to dry season. The reasons can be attributed to the high level purchase of commodities in the festival season and the publication of periodicals, notices and other information bulletins in the festival season.
- The amount of paper waste generation is more in locations near to CBD and high density areas.
- The paper waste is more in houses with household size 5, followed by household size 3, 4 more than 5 and 2. But over the years the paper waste has not been varying with the size of the household. However year wise variation alone is significant in the case of paper waste.
- The quantity of waste generation in the houses which depends on community level disposal methods is more when compared to houses which opt for household level waste disposal.
- The paper waste show their maximum for samples with household income 10000-15000, followed by above 20000, 15000-20000, 5000-10000 and less than 5000. There are significant mean variations within year and between HH income classes. The variations based on household income shows that the quantity of generation of paper waste is directly proportional to the household income up to the class 15000-20000 and then decreases for the income class above 20000.
- For paper waste the row housing units generated more waste followed by individual plots, low rise buildings and high rise buildings. There are significant mean variations within year and between housing units. The quantity of paper waste generation has been on the increase from year to year.
- The paper waste is more in individual owned buildings followed by builder owned and government owned. There are significant mean variations within year and between ownership types. The quantity of paper waste generation has been on the increase from year to year. The amount of paper waste generation is more in individual owned houses followed by builder owned and government owned.

Glass waste

- On an average the glass waste constitutes about 5.1% of total waste which mainly constitutes bottles, storage jars, crockery etc.
- The average glass footprint of the residential areas of Kochi city is 3.28 m^2 per capita which implies that about 3.28 m^2 land area per person is required to assimilate the glass waste generated. This requires 2.92 m^2 of energy land and 0.36 m^2 of built up land.
- The glass waste constitutes maximum during the dry season followed by wet and festival season.
- The amount of glass waste generation is more in locations near to CBD and low density areas.
- The glass waste is more in houses with household size 5, followed by household size more than 5, 4, 3 and 2. The glass waste has been varying significantly with the size of the household. Also the year wise variation is significant.
- The quantity of waste generation in the houses which depends on community level disposal methods is more when compared to houses which opt for household level waste disposal.
- The glass waste show their maximum for samples with household income above 20000 followed by 5000-10000, 10000-15000, 15000-20000 and less than 5000. There are significant mean variations within year and between HH income classes. There are significant mean variations within year and between HH income classes. The temporal variations in the amount of glass waste generation over the years shows that the quantity of glass waste generation has been on the increase from year to year up to 2012 and then shows a decline.
- For glass waste the high rise buildings generated more waste followed by low rise buildings, row housing units and individual plots.
- The glass waste is more in government owned buildings followed by builder owned and individual owned. There are significant mean variations within year and between ownership types.

Metal waste

- On an average the metal waste constitutes about 10.5% of total waste and it includes utensils, equipment parts etc.
- The average metal footprint of the residential areas of Kochi city is 29.12 m^2 per capita which requires 25.89 m^2 of energy land and 3.23 m^2 of built up land for assimilating the wastes generated.
- The metal waste constitutes maximum during the festival season followed by wet and dry season.
- The amount of metal waste generation is more in locations near to CBD and high density areas.
- The metal waste is more in houses with household size 3, followed by household size 5, 4 more than 5 and 2. The solid waste in the form of metal (in kg) has not been varying with the size of the household and there is no variations within the year and both within year and between HH size classes.

- The quantity of waste generation in the houses which depends on community level disposal methods is more when compared to houses which opt for household level waste disposal.
- The metal waste show their maximum for samples with household income above 20000 followed by 10000-15000, 5000-10000, 15000-20000 and less than 5000. There are significant mean variations within year and between HH income classes. The temporal variations in the amount of metal waste generation over the years shows that the quantity of metal waste generation has been on the increase from year to year up to 2012 and then shows a decline. It shows that the metal waste generation is increasing up to income level 10000-15000 and then decreases.
- For metal waste, the low rise buildings generated more waste followed by row housing units, individual plots and high rise buildings. There are no significant mean variations between housing units or within year.
- The metal waste is more in government owned followed by individual owned buildings and builder owned. There are significant mean variations between ownership classes. The amount of metal waste generated is more for individual owned buildings followed by government owned and builder owned.
- There are significant mean variations within year and between ownership types. The quantity of metal waste generation has been on the increase from year to year. The amount of metal waste generation is more in individual owned houses followed by builder owned and government owned.

Organic waste

- On an average the organic waste constitutes about 80.1 % of total waste which mainly include the food waste.
- The average organic footprint of the residential areas of Kochi city is 107.88 m^2 per capita which implies that about 107.88 m^2 land area per person is required to assimilate the organic waste generated. This requires 95.92 m^2 of energy land and 11.96 m^2 of built up land.
- The organic waste constitutes maximum during the festival season followed by wet and dry season. In all the seasons the organic waste constitutes the maximum.
- The amount of organic waste generation is more in locations near to CBD and low density areas.
- The organic waste is more in houses with household size more than 5 followed by household size 5, 3, 4 and 2. There are significant mean variations in the generation of organic waste between the HH size classes. But there are no temporal variations.
- The quantity of waste generation in the houses which depends on household level disposal methods is more when compared to houses which opt for community level waste disposal.
- The organic waste show their maximum for samples with household income 10000-15000 followed by above 20000, 5000-10000, 15000-20000 and less than 5000. There are significant mean variations within year and between HH income classes. The temporal variations in the amount of organic waste generation over the years show that the quantity of organic waste generation has been on the increase from year to year. The variations based on household income shows that the organic waste generation is increasing with the income level up to the income group 10000-15000 and then shows a decline.
- For organic waste the high rise buildings generated more waste followed by row housing units, low rise buildings and individual plots. There are no significant mean variations between housing units or within year.
- The organic waste is more in government owned followed by individual owned buildings and builder owned. there are no significant mean variations between ownership classes or within year

Plastic waste

- On an average the plastic waste constitutes about 1.9 % of total waste and mainly includes the carry bags, utensils, storage bins etc.
- The average plastic footprint of the residential areas of Kochi city is 4.25 m^2 per capita which implies that about 4.25 m^2 land area per person is required to assimilate the plastic waste generated which requires 3.78 m^2 of energy land and 0.47 m^2 of built up land.
- The plastic waste constitutes maximum during the festival season followed by dry and wet season.
- The amount of plastic waste generation is more in locations near to CBD and low density areas.
- The plastic waste is more in houses with household size more than 5 followed by household size 5, 3, 4 and 2. There are significant mean variations within year and between HH size classes. The temporal variations in the amount of plastic waste generation show that the plastic waste that a household is emanating has been on the increase from year to year. The variations based on household size shows that the plastic waste generation is inversely proportional to the household size except for the lowest class and highest class.
- The quantity of waste generation in the houses which depends on household level disposal methods is more when compared to houses which opt for community level waste disposal.

- The plastic waste show their maximum for samples with household income 10000-15000 followed by above 20000, 5000-10000, less than 5000 and 15000-20000. There are significant mean variations within year and between HH income classes. The temporal variations in the amount of plastic waste generation over the years show that the quantity of plastic waste generation has been on the increase from year to year. The variations based on household income shows that the plastic waste generation is highly flexible with income levels.
- For plastic waste the high rise buildings generated more waste followed by individual plots, low rise buildings and row housing units. There are no significant mean variations between housing units or within year.
- The plastic waste is more in builder owned followed by government owned and individual owned buildings. There are significant mean variations between ownership classes. The variations based on ownership shows that the amount of plastic waste generated is more for builder owned buildings followed by government owned and individual owned.

Paper footprint

- On an average the paper footprint comes to 4.06 m^2 per capita which constitutes 2.74% of the total footprint.
- The percentage composition of paper waste in the total waste is 2.6% and the % share to the total footprint value is 2.74%.
- The paper footprint is more in the wet season followed by dry season and festival season.
- The footprint is more in locations near to CBD and in high density areas.
- The paper footprint is inversely proportional to the household size. Also there are significant mean variations within year and between HH size classes. The temporal variations in the paper footprint values over the years show that the paper footprint values have been on the increase from year to year.
- Paper footprint is highest for the income group 5000-10000 followed by the groups above 20000, 15000-20000, 10000-15000 and less than 5000. There are significant mean variations within year and between HH income classes. The temporal variations in the paper footprint values over the years show that the paper footprint values have been on the increase from year to year. The variations based on household income shows that the paper footprint is directly proportional to the household income up to the class 15000-20000 and then decreases for the higher class
- The paper footprint in the houses which depends on community level disposal methods is more when compared to houses which opt for household level waste disposal.
- The paper footprint is more for samples in individual plots, followed by low rise buildings, row housing units and high rise buildings. There are significant mean variations within year and between housing units. The paper footprint values have been on the increase from the year 2010 to the year 2012 and then decreases in the year 2013. The variations based on housing units shows that the paper footprint is high for individual plots followed by row housing units, low rise buildings and high rise buildings.
- There are significant mean variations within year and between ownership classes. The paper footprint values have been on the increasing over the years. The variations based on ownership classes shows that the paper footprint is high for individual owned buildings followed by builder owned and government owned buildings.

Glass footprint

- On an average the glass footprint comes to 3.38 m^2 per capita and constitutes 2.23% of the total footprint.
- The percentage composition of glass waste in the total waste is 5.1% and the % share to the total footprint value is only 2.23%.
- The glass footprint is more in the dry season followed by wet season and festival season.
- Also the footprint is more in locations near to CBD than locations away from CBD.
- The glass footprint is more in high density areas compared to low density areas.
- For glass footprint the footprint values are the highest for samples with household size 2, followed by household size 5, 3, 4 & more than 5. There are significant mean variations between HH size classes. The variations show that the glass footprint is inversely proportional to the household size except for the household size 5.
- The glass footprint show their maximum for samples with household income above 20000 followed by 5000-10000 10000-15000, 15000-20000 and less than 5000. There are significant mean variations within year and between HH income classes. The glass footprint values have been on the increase from the year 2010 to 2012 and then decreases in the year 2013. The variations based on household income shows that the glass footprint is directly proportional to the household income up to the class 10000-15000 and then decreases.
- The glass footprint in the houses which depends on household level disposal methods is more when compared to houses which opt for community level waste disposal.
- The glass footprint is more for low rise buildings followed by high rise buildings, individual plots and row housing unit. There are significant mean variations between housing units. The glass footprint values are high for low rise buildings followed by high rise buildings, individual plots and row housing units.

- The glass footprint shows maximum for the government owned buildings followed by individual owned and builder owned. There are significant mean variations within year. Glass footprint values have been on the increase from year to year up to 2012 and then show a decline.

Metal footprint

- On an average the metal footprint comes to 29.12 m^2 per capita which constitutes 29.12% of the total footprint.
- The percentage composition of metal waste in the total waste is 10.5% and the % share to the total footprint value is only 29.12%.
- The metal footprint is more in the festival season followed by wet season and dry season.
- The footprint is more in locations near to CBD and in high density areas.
- The metal footprint the footprint is inversely proportional to household size. There are significant mean variations within year and between HH size classes. The temporal variations in the metal footprint values over the years show that the metal footprint values have been on the increase from year to year. The variations based on household size shows that the metal footprint is inversely proportional to the household size.
- Metal footprint is highest for the 10000-15000 group followed by the groups 5000-10000, above 20000, 15000-20000 and less than 5000. There are significant mean variations between HH income classes. The variations based on household income shows that the metal footprint is directly proportional to the household income up to the class 10000-15000 and then decreases.
- The metal footprint in the houses which depends on community level disposal methods is more when compared to houses which opt for household level waste disposal.
- The metal footprint values shows maximum in low rise buildings followed by row house buildings, individual plots and high rise buildings. There are significant mean variations between housing units. The metal footprint values are high for low rise buildings followed by individual plots, row housing units and high rise buildings
- The metal footprint shows significant mean variations between ownership classes. The footprint is maximum for the individual owned buildings followed by government owned and builder owned.

Organic footprint

- On an average the organic footprint comes to 107.88 m^2 per capita which constitutes 70.25 % of the total footprint.
- The percentage composition of organic or food waste in the total waste is 80.1% and the % share to the total footprint value is only 70.25 %.
- The organic footprint is more in the festival season followed by wet season and dry season.
- Also the footprint is more in locations near to CBD and high density areas.
- There are significant mean variations between HH size classes. The variations based on household size shows that the organic footprint is inversely proportional to the household size except for the class >5.
- Organic footprint shows maximum for the group 10000-15000 followed by the groups 5000-10000, above 20000, less than 5000 and 15000-20000. There are significant mean variations between HH income classes. The variations based on household income shows that the organic footprint is directly proportional to the household income up to the class 10000-15000 and then decreases.
- The organic footprint in the houses which depends on community level disposal methods is more when compared to houses which opt for household level waste disposal.
- The organic footprint values shows maximum in low rise buildings followed by row house buildings, individual plots and high rise buildings. There are no significant mean variations between housing units or within year.
- The organic footprint shows significant mean variations between ownership classes. The footprint is maximum for the individual owned buildings followed by government owned and builder owned.

Plastic footprint

- On an average the plastic footprint comes to 4.25 m^2 per capita. This constitutes 2.76 % of the total footprint.
- The percentage composition of plastic waste in the total waste is 1.9% and the % share to the total footprint value is only 2.7 %.
- The plastic footprint is more in the festival season followed by wet season and dry season.
- The footprint is more in locations near to CBD and in low density areas.
- The plastic footprint shows maximum value for household size 3, followed by 2, more than 5, 4 and 5. There are significant mean variations within year. Temporal variations in the plastic footprint values over the years shows that the plastic footprint value has been on the increase from year to year.

- There are significant mean variations within year and between HH income classes. The temporal variation in the plastic footprint values shows that the footprint has been on the increase from year to year. The variations based on household income shows that the plastic footprint is directly proportional to the household income up to the class 10000-15000 and then decreases.
- The plastic footprint in the houses which depends on community level disposal methods is more when compared to houses which opt for household level waste disposal.
- The plastic footprint values shows maximum in row house buildings followed by individual plots, low rise buildings and high rise buildings. There are significant mean variations within year and between housing units. The plastic footprint value has been on the increase over the years. The variations based on housing units shows that the plastic footprint is high for row housing units followed by individual plots, low rise buildings and high rise buildings.
- The footprint is more for the builder owned followed by government owned and individual owned buildings. There are no significant mean variations between ownership classes or within year.

Season

In all the seasons the organic waste (food waste) constitutes maximum followed by metal waste, glass waste, paper waste and plastic waste. And so are the footprint values.

Location

The amount of wastes generated in different locations in different seasons is given in Table 4. Table shows that the amount of almost all the wastes in all seasons is more in locations near to CBD/MTN. Over consumption or unnecessary purchases may be reason for increasing the waste generation. Food wastes constitute the highest, followed by the metal wastes and glass wastes.

Table 4. Amount of wastes in kg/day/household based on location in different seasons

Season	Location	Paper	Glass	Metal	Organic waste	Plastic
Dry	Away from CBD/MTN	0.035	0.086	0.166	1.122	0.013
	Near to CBD/MTN	0.036	0.097	0.185	1.192	0.020
Festival	Away from CBD/MTN	0.037	0.076	0.136	1.421	0.026
	Near to CBD/MTN	0.042	0.077	0.176	1.565	0.031
Wet	Away from CBD/MTN	0.036	0.080	0.149	1.319	0.025
	Near to CBD/MTN	0.041	0.086	0.167	1.577	0.027

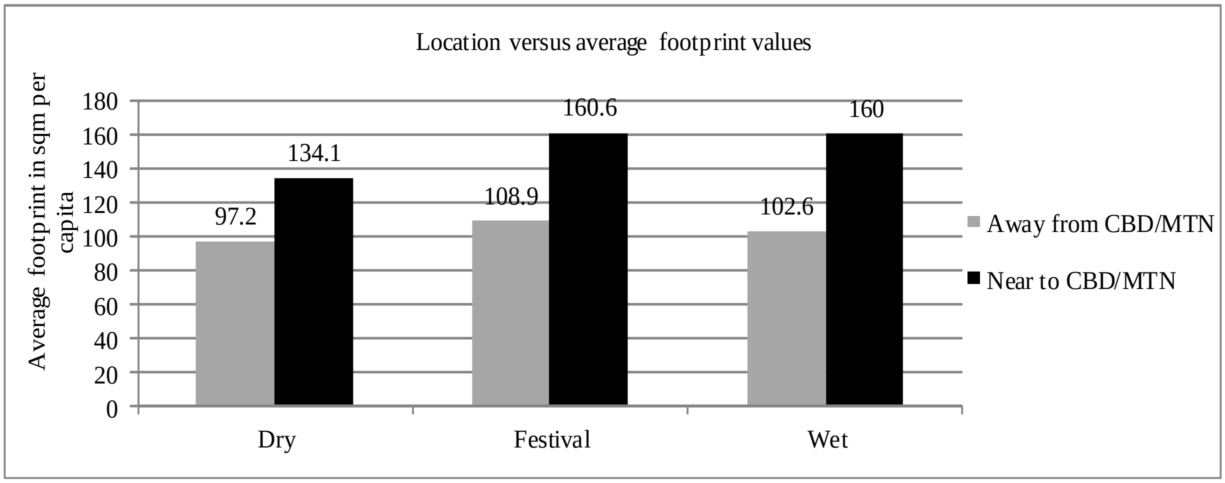

Figure 4. Location versus average foot print

Fig. 4 shows that the average foot print values are high in locations near to CBD/MTN. Residences which are near to CBD/MTN show high footprint values in the wet season and festival season. The footprint value is about 20% more when compared to that of the dry season. A similar trend is also noticed in the residences away from CBD/MTN.

Population density

The analysis showed that as the density of population is increasing the footprint is increasing as the amount of waste generated is more in high density areas as shown in Fig. 5.

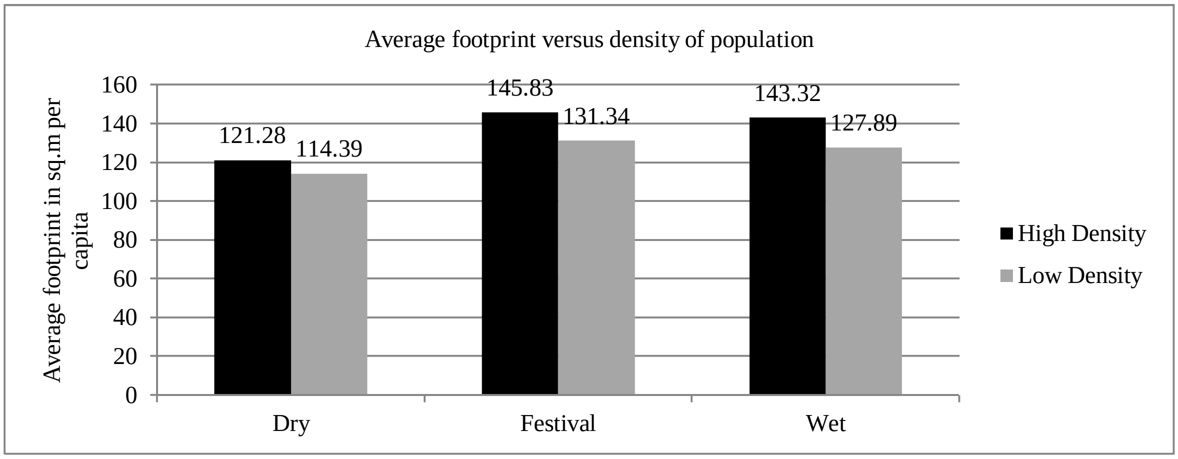

Figure 5. Average footprint versus density of population

The average footprint is more in the festival season. The per capita average footprint in sqm is about 145.83 in the festival season. Table 5 shows the composition of wastes in the high and low density areas in different seasons. The paper content in the dry seasons is high in the high density areas. But during the other seasons the composition of paper waste is more in the low density areas. The glass and metal content shows high composition during the dry and wet season in the high density areas. Organic waste and plastic content is more in the low density areas in all seasons.

Table 5. Density and % composition of waste in different seasons

	High Density			Low Density		
	% Composition			% Composition		
Season	Dry	Festival	Wet	Dry	Festival	Wet
Paper	2.60	2.16	2.15	2.25	2.28	2.24
Glass	6.29	4.00	4.96	6.04	4.30	4.78
Metal	11.32	9.79	10.56	12.37	7.18	7.58
Organic waste	78.89	82.57	81.32	78.07	84.62	83.38
Plastic	0.90	1.48	1.00	1.26	1.61	2.01

Household size

Analysis based on household size and average footprint value showed that the household size is inversely proportional to the average footprint values in all season (Fig. 6). In most cases the footprint value is high in the festival season. The reason can be explained from the Table 6.

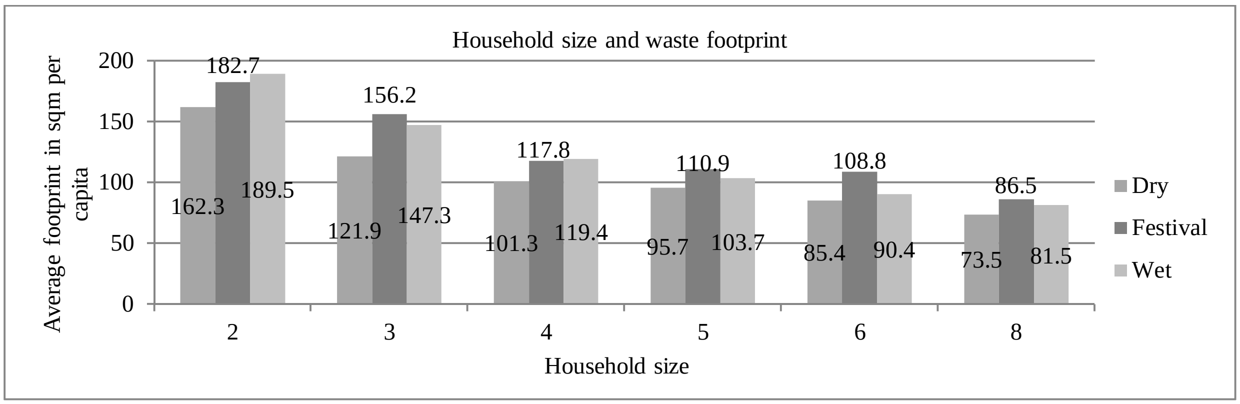

Figure 6. Household size and waste footprint

Table 6. Household size and per capita footprint

Household size	Total quantity of waste generated	Waste generated per person	Average footprint per person
2	9.30	4.65	178.13
3	11.09	3.70	141.59
4	11.78	2.94	112.84
5	13.73	2.75	103.54
6	15.09	2.51	94.82
8	17.30	2.16	80.52

Table 6 shows that the waste generated per person in low household size families are more when compared to families with large household size. This is contributing the high footprint values in families with small household size.

Household income

Analysis based on household income shows that the average footprint is comparatively high for the income group 10000 to 15000 followed by the above 20000 group. The footprint is high in the festival season for all income groups. The lowest contributor to waste footprint is the less than 5000 income group. The comparisons are given in Fig. 7.

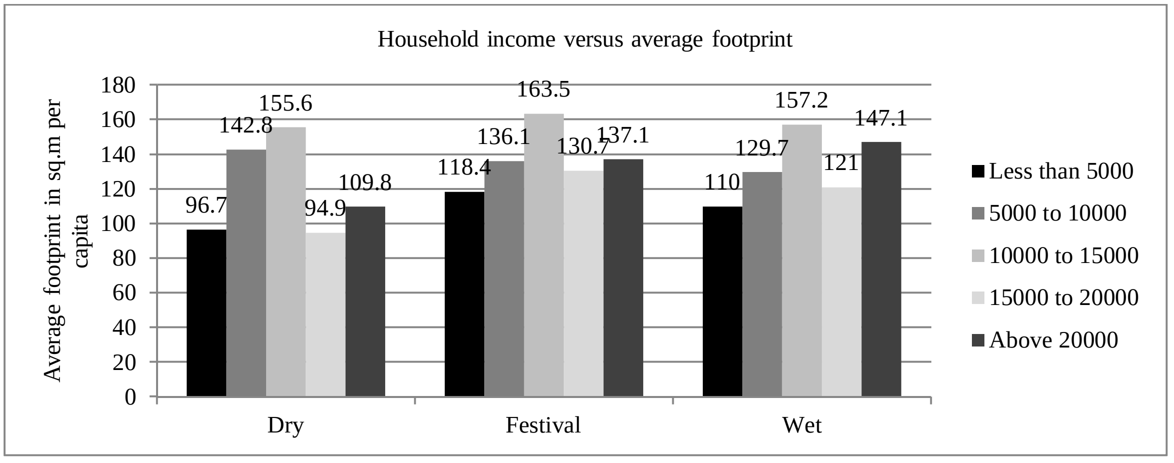

Figure 7. Household income versus average footprint

Waste disposal

Community level disposals show high waste footprint values when compared to household level disposal methods (Fig. 8). The waste footprint values are high in festival season. The low waste footprint values for household level disposals shows that the waste disposal at source itself is a sustainable option for proper solid waste management.

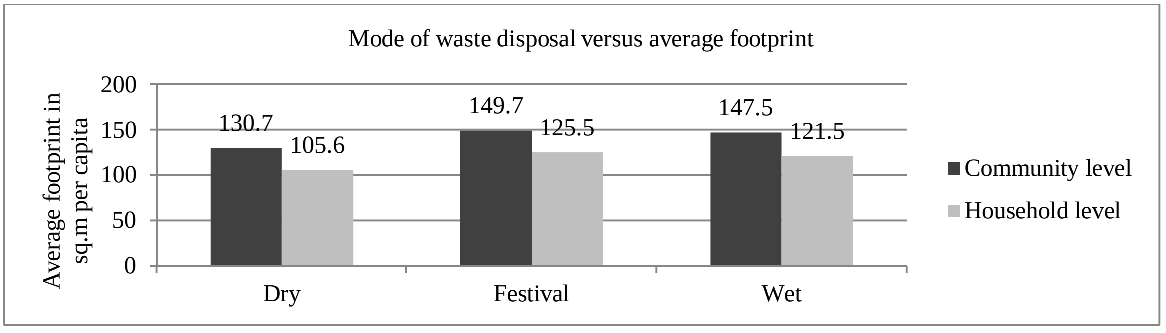

Figure 8. Mode of waste disposal versus average footprint

Housing unit

Analysis based on the housing type is given in Fig. 9. Almost all the housing types show high footprint values in the festival season. The average waste foot print value is comparatively low for individual plots except in festival season.

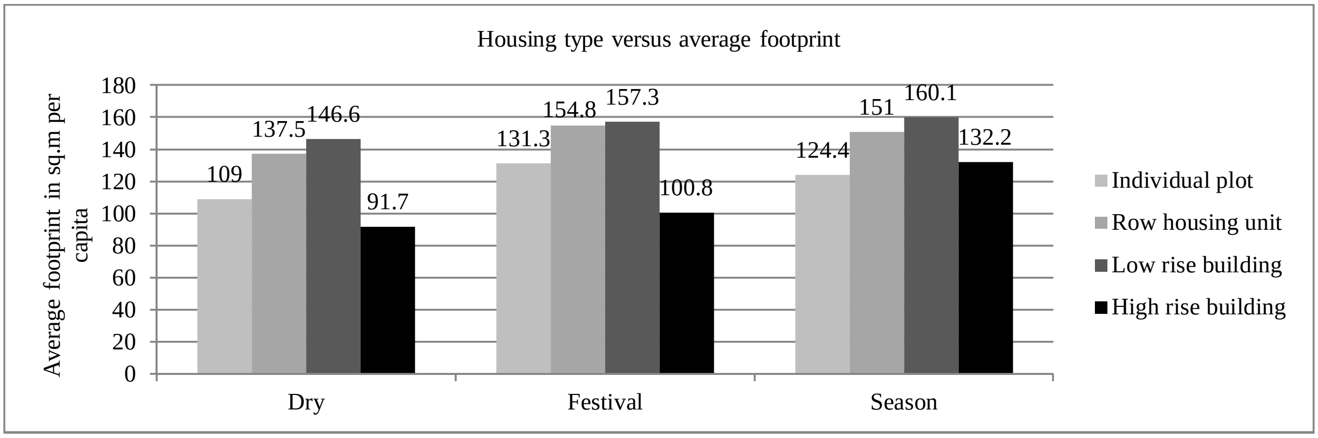

Figure 9. Housing type versus average footprint

Ownership

Residences owned by builders showed low waste footprint values when compared to others. The footprint values in the wet and festival season are also high (Fig. 10).

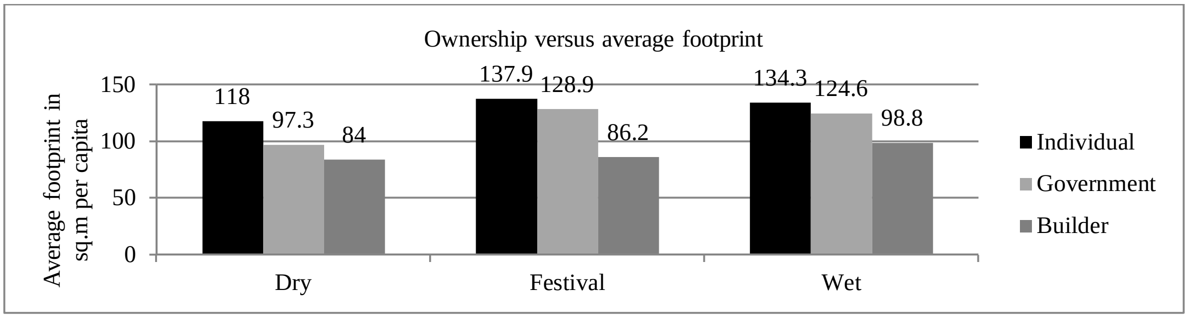

Figure 10. Ownership versus average footprint

Sustainable waste management options for reducing the waste footprint of Kochi city

Waste categories and different recycling levels affecting footprint

Table 7 shows the waste categories and their recycling levels affecting footprint. The ‘present recycling’ in the table meant the recycling rate during the time of primary survey. Since only 53 samples reported paper recycling it is assumed that the 0% paper is recycled. During the primary survey in 2010 and in the surveys conducted in the consecutive years and based on other secondary surveys, it was observed that many recycling initiatives are in the pipeline and at the anvil going to launch in the residential areas of the city. Some of them were the biogas production by Kerala Suchitwa mission, vermi-composting in residential flats by CREDAI Kochi and other programmes by NGOs. The ‘targeted recycling’ is meant in this regard. The ‘projected recycling’ rate is assumed considering the maximum recycling levels practiced in other urban areas that can reduce the waste footprint to considerable levels.

Table 7. Waste categories and different recycling levels affecting waste footprint

Waste Category	Recycling (%)			Waste Footprint (in sqm per capita)		
	Present	Targeted	Projected	Present	Targeted	Projected
Paper	0	60	90	3.26	2.36	1.92
Glass	0	30	50	2.85	2.58	2.42
Metal	0	30	60	23.35	16.69	10.04
Organic waste	0	75	90	96.76	54.67	46.25
Plastic	0	25	50	2.64	2.18	1.72
Total waste footprint (m^2/capita)				128.86	78.48	62.35

The research anticipates a 39% reduction in footprint value through the programmes going to get launched in the city and suburbs. A maximum of 51% reduction in footprint value can be attained through the high optimistic value of recycling.

Different waste generation levels and footprint values

Table 8 which shows the waste categories and different waste generation levels affecting waste footprint showed a proportional decrease in the footprint value with decrease in waste generation. As per the waste management hierarchy theories the source reduction proved the first order hierarchy in waste management in terms of waste footprint values.

Table 8. Waste categories and different waste generation levels affecting waste footprint

Waste Category	Waste generation			Waste Footprint		
	Present kg/capita/day	Targeted reduction (%)	Projected reduction(%)	Present footprint	Targeted footprint	Projected footprint
Paper	0.01	50	80	3.26	1.63	0.651
Glass	0.03	30	50	2.85	1.99	1.42
Metal	0.05	30	50	23.35	16.35	11.68
Organic waste	0.42	50	90	96.76	48.38	9.68
Plastic	0.01	50	75	2.64	1.32	0.66
Total				128.86	69.67	24.09

Combined analysis of waste reduction and recycling

According to the analysis with the recycling techniques proposed to launch in the city and a 50% reduction in paper, organic and plastic and 30% reduction in glass and metal waste generation can cause a 66.5% reduction in the waste footprint value. And in the maximum optimistic level 80% reduction in paper waste generation and 90% recycling of paper, 50% reduction in glass waste generation and with 50% recycling, 50% reduction in metal waste generation and with 60% recycling, 90% organic waste reduction and 90% recycling, 75% reduction in plastic waste and 50% recycling can reduce 91% of the present waste footprint of the city (Table 9).

Table 9. Combined analysis of waste reduction and recycling

Waste Category	Present			Targeted (%)			Projected (%)		
	Generation (kg)	Recycling	Footprint	Reduction in Generation	Recycling	Footprint	Reduction in Generation	Recycling	Footprint
Paper	0.01	0	3.26	50	60	1.18	80	90	0.38
Glass	0.03	0	2.85	30	30	1.81	50	50	1.21
Metal	0.05	0	23.35	30	30	11.68	50	60	5.02
Organic waste	0.42	0	96.76	50	75	27.33	90	90	4.62
Plastic	0.01	0	2.64	50	25	1.09	75	50	0.43
Total	128.86			43.09			11.66		

Conclusion

The paper illustrated that waste foot printing can be used as a tool to assess the impact of waste generation in an area, thereby focusing on the appropriate waste management technique suitable for the area. The waste footprint figures of Kochi city and its analysis showed that by 2051 the whole area of the city corporation will be required to assimilate the waste generated by the residents if the present trend of waste generation exists. This pointed out the highly unsustainability dilemma existing in the residential areas of Kochi city in the case of waste management. The analysis based on the different criteria showed that several social and economic factors are also affecting the waste footprint in addition to the technical or engineering factors. In addition to technical or engineering innovations in waste management a shift in the mindset of the people or an awareness creation is absolutely essential for the sustainable waste management of the area.

The analysis of various options which can reduce the waste footprint of the city highlights that waste reduction practices especially for organic waste and paper and the options for recycling can reduce the waste footprint of the residential areas of Kochi City to a considerable extent. Therefore organic waste reduction and recycling techniques should be encouraged in the city. Further studies in this regard can be framed to assess the sustainability of various organic waste management and recycling techniques.

The waste footprint can calculate the impact of waste generation of a single individual. This aspect of the concept is to be utilized and a model for calculating the waste footprint of a single individual in the city can be developed and the model is to

be made available through the social media. Thus the individual households in the city can calculate their waste footprint from their home by simply entering their amount of waste generation and their social and economic aspects. This will make them able to compare the footprint values with their neighboring houses, friends and colleagues and act in a positive manner.
On the other hand the policy makers can set strategies for sustainable solid waste management based on the waste footprint values or monitor the waste footprint values of the individuals so as to set limits for waste generation. This will become more effective if the equations for waste footprint calculations are generated specifically for the area under study. For this research and development studies should be initiated at the country level.
With this the paper concludes that waste foot printing technique is an apt tool for quantifying the waste generated which will help in technical and engineering innovations in waste management. At the same time it can used as an awareness or mind set change tool for sustainable solid waste management. The waste footprint study of Kochi city can be used as a pilot project in the country and more research and development projects regarding waste foot printing could be initiated at the country level, state level and local body level.

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