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SUSTAINABLE SOLID WASTE MANAGEMENT SOLUTIONS TO KOCHI CITY, INDIA, THROUGH THE ENVIRONMENTAL MANAGEMENT TOOL ECOLOGICAL FOOTPRINT ANALYSIS

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ABSTRACT

Solid waste management nowadays is an important environmental issue in country like India. Statistics show that there has been substantial increase in the solid waste generation especially in the urban areas. This trend can be ascribed to rapid population growth, changing lifestyles, food habits, and change in living standards, lack of financial resources, institutional weaknesses, improper choice of technology and public apathy towards municipal solid waste. Waste is directly related to the consumption of resources and dumping to the land. Ecological footprint analysis – an impact assessment environment management tool makes a relationship between two factors- the amount of land required to dispose per capita generated waste. Ecological footprint analysis is a quantitative tool that represents the ecological load imposed on the earth by humans in spatial terms. By quantifying the ecological footprint we can formulate strategies to reduce the footprint and there by having a sustainable living. In this paper, an attempt is made to explore the tool Ecological Footprint Analysis with special emphasis to waste generation. The paper also discusses and analyses the waste footprint of Kochi city,India. An attempt is also made to suggest strategies to reduce the waste footprint thereby making the city sustainable, greener and cleaner.

KEYWORDS: Ecological Footprint Analysis, Sustainable Solid Waste Management, Kochi City

INTRODUCTION

Kochi City

Kochi, affectionately called the 'Queen of the Arabian Sea', is located on the west coast of India, in the beautiful state of Kerala. This city in the district of Ernakulum can be regarded as the commercial and industrial capital of Kerala. Kochi city is the second most important city next to Mumbai on the western cost of India. Cochin Corporation has an area of 94.88 sq.km. and is divided into 66 wards (administrative division). Kochi is the most urbanized region in Ernakulam district. As per census of India 2001, the population of Kochi Corporation is 5,95,575. Physical, social, political and economic factors have played their decisive role in the formation of land use pattern in Kochi city. Constraints of landforms and lagoon system contributed to the concentration of economic activities to the water front areas. The existing land use pattern has resulted from the complex interactions of varied factors in the urban structures. The characteristic feature of the central city is the predominance of the area under water. The water sheet consists of backwaters, rivers, canals, tanks and ponds and altogether it forms 23.4% of the green land of the city. The net dry land available for urban use amounts to 71.86% of the gross land i.e. 68.18 sq. km. Truly there could be no ideal location than this, with its protected lagoons directly accessible from the sea, for a major terminal port and with its hinterland bountifully blessed by nature for a concentration of urban population and activities. But the present pattern of the city can be classified as that of haphazard growth with typical problems characteristics of unplanned urban development.

Ecological Footprint Analysis

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.

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.

Basically, the aim of ecological footprint analysis is to quantify the consumption and waste generation of a population and to compare it with the existing biocapacity. By quantifying the ecological footprint we can formulate strategies to reduce the ecological footprint and there by having a sustainable living. The ecological footprint of waste generation provides per capita land requirements for waste generation. Thus calculating the footprint for an area, the ecological footprint can be a tool for sustainable environmental management as:

- The calculation of ecological footprint of food can suggest strategies and create awareness to reduce the food consumption, change the food composition, reduce the food waste, increase the efficiency of food production and improve the efficiency of food distribution and delivery.
- The calculation of ecological footprint of waste generation is the primary and basic stage of sustainable waste management
- The calculation of goods and services footprint can suggest strategies to reduce the demand or to shift the demand for goods and services, to prolong the life span of products, to purchase goods that are sourced and manufactured locally.
- The calculation of shelter footprint can formulate strategies to reduce the house area usage, reduce energy demand for housing .
- The calculation of mobility footprint can formulate urban planning measures and to propose a mode shift to reduce the mobility foot print.
- The calculation of waste can determine the land required to assimilate the waste generated in present and future.
- Calculation of footprint is handy for selection of disposal site like land required for disposal, disposal site characteristics determination based on the footprint of waste components, etc.
- The design of landfill site can be supported through the footprint calculation of wastes providing information on land required for different components of wastes.
- Selection of the suitable site for landfill can be supported through footprint calculation as the calculation provides the information on land requirement in the predicted future. Thus many suitable sites can be selected if the requirement can be known.
- To determine the importance of recycling of different waste categories in order to reduce the footprint.

Table 1: Comparison of EFA and EIA

EFA	EIA
Impact of a single man can be measured.	Impact of a single man can be measured. But done mostly for large projects.
Energy consumption is given due consideration.	Did not have an analysis on the energy consumption.
Quick and easy	Time consuming
There are many softwares developed for the quantification of the impacts and with these technologies the analysis can be made quick and easy.	Since the preparation of the environmental statement is done by the members of the expert committee, the difference in their views will lead to cost and delays consequent on preparation of impact statements.
Impacts are quantified and compared with the capacity.	Impacts are quantified to an extend only.
Can accurately measure how far we are away from sustainability.	Tries to keep a balance only in the environmental aspects.
Whoever assesses the impact, the result will be the same.	Changes will depend on the views of the expert committee
Criteria for assessment vary depending on the region and depending on the time when it is assessed.	Criterion for assessment is purely developed by foreign agencies.

Limitations of EFA are

The ecological footprint is *one* indication of unsustainability. Because of the limitations below, we can say that "x is unsustainable because it's ecological footprint exceeds the fair share" but you cannot say "x is sustainable because it fits within the fair share"; we would then need to account for pollution, water use, toxicity, health, happiness, and so on. The accuracy of any given footprint analysis is also constrained by the quality of the data. Because of these limitations, ecological foot printing should be used as one tool amongst many.

THE ECOLOGICAL FOOTPRINT AND SUSTAINABLE ENVIRONMENTAL MANAGEMENT

Basically, the aim of ecological footprint of waste in sustainable management system is to achieve regulatory compliance and potentially improve performance. However, the ecological footprint of waste generation provides per capita land requirements for waste generation. Thus calculating the footprint for an area, the ecological footprint can be a tool for sustainable environmental management as:

- The calculation of ecological footprint of waste generation is the primary and basic stage of sustainable waste management to determine the land required to assimilate the waste generated in present and future.
- Calculation of footprint is handy for selection of disposal site like land required for disposal, disposal site characteristics determination based on the footprint of waste components, etc.
- The design of landfill site can be supported through the footprint calculation of wastes providing information on land required for different components of wastes.
- Selection of the suitable site for landfill can be supported through footprint calculation as the calculation provides the information on land requirement in the predicted future. Thus many suitable sites can be selected if the requirement can be known.
- Determining the importance of recycling of different waste categories in order to reduce the footprint.

Methods for Calculating the Ecological Footprint for Waste Generation

In calculating the ecological footprint for household waste generation, methodology to assess the household ecological footprint, developed by Mathis Warckernagel, Ritik Dholakia, Diana Deumling and Dick Richardson, Redefining Progress v 2.0, March 2000, can be used. The methodology utilizes the resource consumption and waste generation categories and the land use categories for those consumption and waste generation.

Land Use Categories for Estimating Ecological Footprint

The Land Use Categories Are Summarized as

- Energy Land: The area of forest that would be required to absorb the CO2 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.

Generalized Procedure

- The sum of the land requirements for the six individual land categories represents the community's ecological footprint.
- The methodology presents all results in per capita figures. Multiplying the per capita data by the selected area's population gives the total footprint of that area.
- The EF is expressed in land "area units" (in hectares) where each area unit corresponds to one hectare of biologically productive space with world-average productivity.
- To calculate the ecological footprint of waste generation, the generated waste is categorized as paper, plastic, glass, metal, aluminum and organic waste.

Underlying Equations for Calculation

The biologically productive land required for this waste generation are calculated by some equations, which are given below:

A. Biologically productive land required for paper

Energy land = world energy yield * energy intensity of paper * (amount of per capita paper waste per year / waste factor of paper) * (1 – % of recycling of paper * % of energy saved from recycling)…… (i)

Where,

- The energy yield (assumed to be average fossil fuel = liquid fossil fuel) is 73000 Mj / 10000 m^2-year.
- Energy intensity of paper is 35 Mj/kg.
- Waste factor is the percentage of paper consumed.

Forest land = World average yield of round wood * ratio of round wood needed per unit paper * (amount of per capita paper waste per year / waste factor of paper) * (1 - % of recycling of paper * % energy saved from recycling)……………………………(ii)

Where,

- World average yield of round wood is 10000/2.6 m^3/hectare.
- Ratio of round wood needed per unit paper is 1.65/1000.
- Waste factor is the percentage of paper consumed.

Built up land = Energy land required for paper waste * built up land footprint component of waste / (world average fossil fuel area of goods + world average fossil fuel area of waste) / primary biomass equivalence factor for built up area………………(iii)

Where,

- Energy land required for paper waste get from equation no. (i)
- Built up land footprint component of waste is 1100m^2.
- World average fossil fuel area of goods is 1324 hector.
- World average fossil fuel area of waste is 1196 hector.
- Primary biomass equivalence factor for built up area is 3.5

B. Biologically productive land required for plastic

Energy land = world energy yield * energy intensity of plastic * per capita amount of plastic waste per year (1- % of recycling of plastic waste*energy saved from recycling of glass waste)………..(iv)

Where,

- The energy yield (assumed to be average fossil fuel = liquid fossil fuel) is 73000 Mj / 10000 m^2-year.
- Energy intensity of plastic is 50 Mj/kg

Built up land =Energy land required for plastic waste * built up land footprint component of waste / (world average fossil fuel area of goods + world average fossil fuel area of waste) / primary biomass equivalence factor for built up area……………… (v)

Where,

- Energy land required for plastic waste get from equation no. (iv)
- Built up land footprint component of waste is 1100m^2.
- World average fossil fuel area of goods is 1324 hector.
- World average fossil fuel area of waste is 1196 hector.
- Primary biomass equivalence factor for built up area is 3.5

C Biologically productive land required for glass

Energy land = world energy yield * energy intensity of glass* per capita amount of glass waste per year (1- % of recycling of glass waste*energy saved from recycling of glass waste)…………………….(vi)

Where,

- The energy yield (assumed to be average fossil fuel = liquid fossil fuel) is 73000 Mj / 10000 m^2-year.
- Energy intensity of glass is 15 Mj/kg

Built up land = Energy land required for glass waste * built up land footprint component of waste / (world average fossil fuel area of goods + world average fossil fuel area of waste) / primary biomass equivalence factor for built up area………………………(vii)

Where,

- Energy land required for glass waste get from equation no.(vi)
- Built up land footprint component of waste is 1100m^2.
- World average fossil fuel area of goods is 1324 hector.
- World average fossil fuel area of waste is 1196 hector.
- Primary biomass equivalence factor for built up area is 3.5

D. Biologically productive land required for metal

Energy land = world energy yield * energy intensity of metal* per capita amount of metal waste per year (1- % of recycling of metal waste*energy saved from recycling of metal waste)…………………….(viii)

Where,

- The energy yield (assumed to be average fossil fuel = liquid fossil fuel) is 73000 Mj / 10000 m^2-year.
- Energy intensity of metal is 60 Mj/kg

Built up land = Energy land required for metal waste * built up land footprint component of waste / (world average fossil fuel area of goods + world average fossil fuel area of waste) / primary biomass equivalence factor for built up area………… (ix)

Where,

- Energy land required for metal waste get from equation no. (viii)
- Built up land footprint component of waste is 1100m^2.
- World average fossil fuel area of goods is 1324 hector.
- World average fossil fuel area of waste is 1196 hector.
- Primary biomass equivalence factor for built up area is 3.5

E. Biologically productive land required for Organic waste (food)

Energy land = world energy yield * energy intensity of organic waste* per capita amount of organic waste per year * (1- % of recycling of organic waste*energy saved from recycling of organic waste)……….(x)

Where,

- The energy yield (assumed to be average fossil fuel = liquid fossil fuel) is 73000 Mj / 10000 m^2-year.
- Energy intensity of organic waste is 30 Mj/kg
- The amount of recycling of organic waste is equal to the amount of composting
- Energy saved from the recycling of organic waste is determined by the following way:
  - Calculating the amount of biogas from the organic waste.
  - Calculating the energy production from that biogas.
  - Calculating the percentage of energy getting from organic waste.

Biogas Production

The amount of biogas (X) generated from total areas is calculated from the relation: (Biswas and Lucas, 1996).

X (m^3) =Raw material (solid waste, kg) x TSC (Total solid content) x Gas generation rate per unit of solid (m^3/kg).

Energy Production

The expected amount of energy from biogas in total areas is

E1 (kJ) = X (m^3) x (%) of methane x LHV (kJ/m^3)Lower heating value

Percentage of Energy Saved from Organic Waste

Built up land = Energy land required for organic waste * built up land footprint component of waste / (world average fossil fuel area of goods + world average fossil fuel area of waste) / primary biomass equivalence factor for built up area…………… (xi)

Where,

- Energy land required for metal waste get from equation no. (x)
- World average fossil fuel area of goods is 1324 hector.
- World average fossil fuel area of waste is 1196 hector.
- Primary biomass equivalence factor for built up area is 3.5

F. Obtaining the total footprint for waste generation

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 ecological footprint of waste generation.

WASTE FOOTPRINT OF KOCHI CITY

For the detailed study of waste footprint of the city, a questionnaire survey was conducted for 500 samples in three different seasons i.e dry(April 2010 and December 2010-January 2011),wet (July 2010) and festival season (August 2010), inside the Corporation boundary and random samples in the outskirts. For calculating the waste foot print , the waste generated in the city was categorised into paper, glass, plastic, metal and organic waste. Analysis of the data was done using waste footprint analyser, which is a program developed for inputting the survey data and estimating the footprint values in a visual basic platform. The analyser generated the footprint value in hectares per capita. Following are the results obtained.

- In all the seasons the organic waste constitutes more than 70%.
- Paper waste constitutes more than 10%.
- Plastic waste consitutes more than 5%.

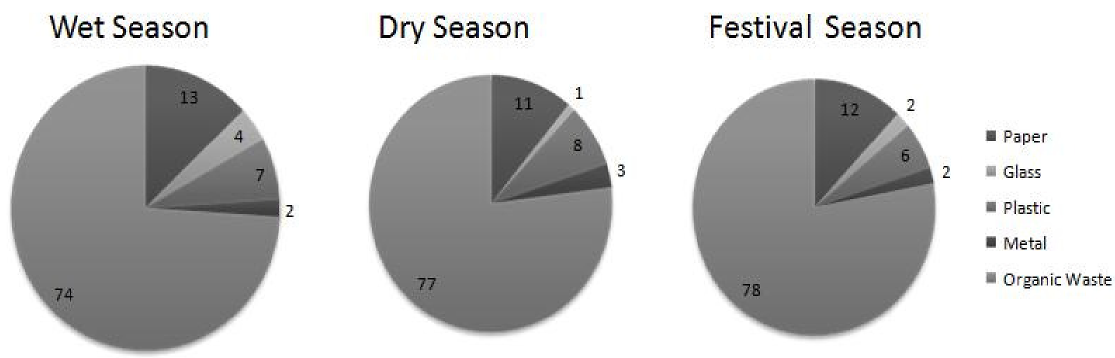

Figure 1: Category Wise Waste Comparison in Three Different Seasons

Waste Footprint of Categories of Waste & Seasonal Variation

The total waste footprint value is low in the dry season and increases in the wet season and higher in the festival season. For glass and metal waste the trend is reversing.

Table 3: Biological Productive Land Requirement of Different Categories of Waste

Season	Biological Productive Land Requirement -Waste Footprint (in Sqm Per Capital Per Year)					Total
	Paper	Glass	Metal	Organic Waste	Plastic	
Dry	2.96	3.03	24.67	82.54	10.70	123.9
Wet	3.11	2.87	22.86	102.31	14.00	145.1
Festival	3.22	2.59	22.10	105.33	14.55	147.7

Waste Footprint of Categories of Waste & Density of Population

From Table 4 we can infer that as the density increases the waste footprint value also increases. Organic waste foot print constitutes highest followed by Metal waste and Plastic waste. Paper waste footprint is low in the high density areas.

Table 4: Biological Productive Land Requirement for Different Density of Population

Density	Biological Productive Land Requirement (in Sqm)					Total
	Paper	Glass	Metal	Organic Waste	Plastic	
High	3.05	2.99	26.05	101.77	13.3	147.16
Low	3.15	2.68	20.1	91.12	12.84	129.89

Waste Footprint of Categories of Waste & Location

The waste footprint value is higher in areas near to CBD/MTN.But organic waste footprint is low in areas away from CBD/MTN.Metal and plastic footprint shows nearly double values in areas near to CBD/MTN.

Table 5: Biological Productive Land Requirement for Different Location of the Residence

Location	Biological Productive Land Requirement (in Sqm)					Total
	Paper	Glass	Metal	Organic Waste	Plastic	
Away from CBD/MTN	2.85	2.32	17.27	96.52	10.36	129.32
Near to CBD/MTN	3.32	3.28	28.36	95.37	16.72	147.05

Waste Footprint of Categories of Waste & Income of Population

The waste footprint increases up to 10000 to 15000 income group and is highest in that group.

Table 6: Biological Productive Land Requirement of Different Categories of Income

Household Income	Biological Productive Land Requirement (in Sqm)					Total
	Paper	Glass	Metal	Organic Waste	Plastic	
Less than 5000	1.56	0.77	11.23	90.84	13.01	117.4
5000 to 10000	3.18	2.58	20.29	97.8	12.51	136.3
10000 to 15000	3.17	3.64	33.54	121.84	16.52	178.7
15000 to 20000	3.24	2.72	20.54	90.55	12.65	129.7
above 20000	3.2	3.25	27.6	96.15	13	143.2

Waste Footprint of Categories of Waste & Family Size

Waste footprint versus family size shows vague results. This may be due to defects in sample.

Table 7: Biological Productive Land Requirement and Family Size

Household Size	Biological Productive Land Requirement (in Sqm)					Total
	Paper	Glass	Metal	Organic Waste	Plastic	
2	4.1	3	31	136	18	192.10
3	3.43	2.82	25.8	106.8	14.29	153.14
4	2.9	2.91	21.57	83.29	11.1	121.77
5	2.38	2.87	17.23	78.78	10.68	111.94
>5	1.38	1.79	11.77	77.18	11.25	103.37

Waste Footprint of Categories of Waste & Mode of Waste Disposal

The low footprint values at the household level disposal indicate the importance of waste disposal at the source.

Table 8: Biological Productive Land Requirement and Mode of Waste Disposal

Mode of Waste Disposal	Biological Productive Land Requirement (in Sqm)					Total
	Paper	Glass	Metal	Organic Waste	Plastic	
Household Level	3.04	2.68	17.90	82.30	11.04	116.96
Community Level	3.14	2.97	27.78	109.25	14.84	157.98

Waste Footprint of Categories of Waste & Type of Housing Unit

Waste footprint is highest for row housing units and low rise buildings as shown in Table 9.

Table 9: Biological Productive Land Requirement and Type of Housing Unit

Housing Unit Type	Biological Productive Land Requirement (in					Total
	Paper	Glass	Metal	Organic Waste	Plastic	
Individual Plot	3.35	2.40	19.71	85.00	11.64	122.10
Row Housing Unit	2.92	4.01	32.12	116.47	15.30	170.82
Low Rise Building	2.90	4.01	32.00	116.00	15.30	170.21
High Rise Building	2.47	3.87	19.80	89.40	12.38	127.92

Waste Footprint of Categories of Waste & Effect of Recycling

Except for paper no active recycling methods inside the city and outskirts. Only 42 Organic waste recycling samples were surveyed. Samples having recycling methods show 58% footprint reduction.

STRATEGIES TO REDUCE SOLID WASTE FOOTPRINT

To reduce the waste footprint following strategies may be adopted.

State Level

- Introduce a recycling department for the state
- Identify local bodies which offer less economic development and give offer to them to act as ‘kidneys’ of the rest of the population, without affecting the social life of the people but enhancing the economic development by processing the population’s waste into valuable products like manure, recycled products etc.
- Invest in R& D to identify new uses for waste products(for e.g. clothing from PET plastic etc.) and through market intervention to reduce the prices of recycled products.
- Make use of the waste footprint analyser to assess the waste footprint of the population at individual level.

City Level

- Create awareness among the population
- Enable reuse and recycling centres to reuse waste materials disposed of at these sites through the resale of reusable items
- Sustain a give and take relationship with suburban local bodies
- Charge people on the basis of volume of waste and frequency of collection.

- Charge people on the basis of weight of the waste collected
- Offer incentives to households to produce less waste.

Community Level

- Introduce a kerbside collection scheme for recyclables from all homes in the city, supported by a network of recycling centres for residents to ‘ drop off’ recyclable materials.
- Communicate through residential associations the various effects of solid waste management problems.
- Share new ideas and techniques of effective solid waste reduction and disposal methods

Household Level

- Promote home and community composting in the city.
- Home and community composting may be promoted through the provision of biogas plants at low cost or with subsidies.

Individual Level

- Change mind set of the people regarding waste disposal and other issues. The individual should be aware that they are generating source and only they can
- Observe and compare the individual waste footprint regularly so that the individual can stick on to the techniques of waste reduction and disposal techniques which offer low footprint values thereby less harming the environment.

CONCLUSIONS

The Ecological footprint has a higher flexibility as it can be used for many different purposes. Waste footprint of the Kochi city population is 0.0139 hectares per capita per year. By 2033 the population will need about the full area of the city to assimilate the generated waste if this trend exists. Recycling reduces about 58% of the waste footprint. Consumption rate can be reduced by prioritizing strategies based on the component footprint values starting from the individual level. By measuring consumption rather than pollution, EFA brings sustainable development home, and implicates each of us by the individual and collective decisions we take.

The waste footprint analyzer developed will allow the public to some extent to compare their current profile of consumption and waste generation to a profile which reduces their ecological footprint. For effective footprint reduction through strategies, regions should develop their own ecological footprint calculators based on their consumption pattern and life style of the population. This calculator should be made available to the public through media. Provision should also be given in the calculator so that they can compare their current profile of consumption and waste generation to a profile which reduces their ecological footprint.

This will make the Ecological Footprint Analysis a public awareness tool in addition to a technical tool. This will make Kochi greener, cleaner, safer and self sustainable as in our good old days.To develop a calculator for urban Kerala, corresponding footprint studies must be initiated at the national level. Therefore ecological footprint studies should be encouraged through R&D programmes and a footprint calculator should be developed especially for the urban areas of India.

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