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WASTE FOOTPRINT OF KOCHI CITY, KERALA, INDIA – A STATISTICAL ANALYSIS

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ABSTRACT The wastes produced during premodern era were 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 the statistical analysis of the waste foot print of residential areas of Kochi city.

KEYWORDS : solid wastes, industrialization, urban centers, waste footprint, statistical analysis, Kochi city

INTRODUCTION

Urbanization is the movement of people from rural to urban areas (Datta, 2006; Davis, 1965, Vlahov et al., 2002; Sadorsky, 2013). 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 (Dimpal, 2012). 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 (Varma,2007). The biodegradable wastes of the urban centres 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 (Minghua et al., 2009). 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 (Varma, 2007). 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. This paper gives the statistical analysis of the waste footprint, of the residential areas of Kochi city, Kerala, South India.

THE STUDY AREA – KOCHI CITY

Kochi (formerly Cochin) city is in the Ernakulam District of Kerala, is the second most important port city in the western coast of India and is the commercial capital of the State. The city is located in Ernakulam District, between 760 14' and 760 21' East longitude and 90 52' and 100 1' North Latitude. (Ravi and Subha, 2011).

The Corporation of Kochi is the largest municipal corporation in Kerala both in area and population. The Kochi Municipal Corporation extends to an area of 94.88sq.km. As per census of India 2001, the population of Kochi Corporation is 5, 95,575 and as per census 2011 the population is 6,01,574 (Subha and Ravi, 2014). Kochi has been pushing its borders over the last decade relentlessly, throwing to wind all cautioning by planners that a city without a plan, without public spaces and without respect for its fragile ecological conditions can prosper only at a high cost. Rampant shortage of drinking water is just one. The condition of the roads, traffic congestions on arterial roads, little space for pedestrians and cyclists, rising levels of noise and air pollution, solid waste management nuisance are the others. The difficulty has been aggravated by lack of effective legislation, inadequate funds and services, and inability of municipal authorities to provide the services cost-efficiently. In the eye's of an ordinary man, the condition of the city is very bad in the present stage of unplanned manner especially in the case of solid waste management (Minghua et al., 2009) and transport system, and would wonder what will happen in the future if the city is raised to a metropolitan status.

WASTE FOOTPRINT

Ecological footprint analysis (EFA) 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 William Rees and Mathis Wackernagel at the University of British Columbia. The ecological footprint 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 (Wackernagel and Rees, 1996). The footprint is the area, expressed in global hectares (gha), needed to keep producing the food and fibre we use, absorb our wastes, generate the amount of energy we consume and provide the space for the roads, buildings and other infrastructure we rely on.

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 (Salequzzaman et al., 2006). 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 (Salequzzaman et al., 2006).

WASTE FOOTPRINT OF KOCHI CITY – A STATISTICAL ANALYSIS

For the detailed study of waste footprint of the city (Ravi and Vishnudas, unpublished), a survey was carried out with a participatory research (Pretty and Ward, 2001) using a structured questionnaire. The questionnaire survey was conducted for 500 representative samples in three different seasons i.e dry, wet and festival season, inside the Corporation boundary and random samples in the outskirts. The samples were selected based on 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) and ownership of the building (individuals, government, builders). Samples were selected in such a way to include as many samples in these criteria.

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 periodicals. The amount of glass and metal waste generated in a week was taken in account. In calculating the ecological footprint for household waste generation, methodology to assess the household ecological footprint, developed by M. Wackernagel and W. Rees were used. This study followed the simple methodology (Salequzzaman et al., 2006) applied to a particular area in Bangladesh. This methodology used global carrying capacity standards and utilizes the resource consumption and waste generation categories and the land use categories for those consumption and waste generation.

Analysis of the data was done using 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, the authors of the concept. The analyser was used 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.

In order to statistically analyse the data regarding waste footprint calculations in Kochi city, dependent and independent variables were identified from the survey data. The dependentant variables identified are the amount of paper, glass, metal, organic and plastic waste and the corresponding footprint values. The independent variables are season, location with respect to Central Business District (CBD)/Major Transportation Node (MTN), population density (Popln density), household size (HH size), household income (HH income), waste disposal, housing unit and ownership. The independent variables consist of different types/classes. The variable season has three classes: dry, wet and festival; location: near to CBD/MTN and away from CBD/MTN; population density: high and low; household size: 2,3,4,5 and more than 5; household income: less than 5K (1K= Rs. 1000/-), 5K-10K, 10K-15K,15K-20K and above 20K; mode of waste disposal: household level and community level; type of housing unit: individual plot; row housing unit; low rise building and high rise building; and ownership: individual, government and builder. The statistical analysis of the waste footprint values for the dependent variables with respect to the independent variables has been done separately for the four consecutive years (2010 – 2013). The combined analysis of variations of the dependent and independent variables over the years were also carried out.

For the year wise analysis of each category of wastes and footprint values (dependent variables) with respect to independent variables, ANOVA analysis was carried out for each year (2010-2013). To analyse the variations in quantity of wastes and footprint values with respect to the independent variables over the years, homogeneity of error variance across all years were tested for significance, by doing Bartelett'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 was 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.

RESULTS AND DISCUSSIONS

Year wise analysis

Yearly variations with respect to seasons

The analysis showed, that only organic and plastic waste showed significant variations in all the years 2010-2013. The paper waste generation showed significance only in the year 2010. The paper waste generation in the base year (2010) showed highest generation in the festival season followed by wet and festival season. The organic waste showed highest value in the festival season followed by wet and dry season. The plastic waste generation in the base year (2010) showed highest value in the festival season followed by wet and dry season. But in the years 2011-2013, the plastic waste generation in the dry season is more than that in wet season. Only organic and plastic footprint values showed significant variations over the years 2010-2013. The variation of the footprint values of these wastes with respect to seasons showed similar variations with that of the quantity of wastes generation as explained above. The high quantity of waste generation in the festival season can be attributed to the purchase of new commodities and the reliance of packed food items in the festival season.

Yearly variations with respect to location

The variation of metal, organic and plastic waste is significant (2010) and the quantity of paper waste generation is significant (2011 and 2013) with respect to location of house. The metal, organic and plastic waste generation in the base year showed that, the waste generation in locations near to CBD/MTN is more when compared to generation in locations away from CBD/MTN. This can be attributed to the over consumption of the people living in the CBD areas and the dependency on readymade goods and fast foods. The paper waste generation in the year 2011 and 2013 showed similar variations. The generation of paper waste in these years showed that, the generation is more in locations near to CBD/MTN when compared to the generation in locations away from CBD/MTN.

The variations in the footprint values with respect to location showed that that, all the footprint values in the base year showed significance whereas, only the paper footprint values showed significance in all the years. The paper footprint values show maximum values in the locations near to CBD/MTN. The glass, metal, organic and plastic footprint (2010) also showed maximum values in the locations near to CBD/MTN.

Yearly Variations with respect to Population Density

The variation in the quantity of wastes with respect to population density showed that there are no significant mean variations in the case of generation of wastes with respect to density of the area except for paper (2011 and 2013). The paper generation is more in low density areas compared to high density areas. The density variations in footprint values show that, only paper footprint values are significant (2012 and 2013).

Yearly Variations with respect to Household Size

The variations based on household size in the quantity of wastes and footprint showed that, there are significant variations for glass, organic and plastic wastes in all the years, whereas the paper and metal waste variations are significant in the base year only. The paper waste generation in the base year (2010) is more in houses with household size five (HH5), followed by household size three (HH3), four (HH4), more than five (HH>5) and two (HH2). The generation of glass waste in all the years (2010-2013) is more in HH5 followed by HH>5, HH4, HH3 and HH2. Metal waste was more on the festival season followed by wet and dry season. The metal waste generation in the base year (2010) is more in HH3, followed by HH5, HH4, HH>5 and HH2. The organic waste and plastic waste generation (2010-2013) is more in houses with HH>5, followed by HH5, HH3, HH4 and HH2.

The variations based on the household size in the footprint values showed that the all the footprint values are significant in all the years (2010-2013). The paper footprint and the organic waste footprint are inversely proportional to the household size. For glass footprint the footprint values are the highest for HH5, followed by HH2, HH3, HH4 and HH>5. The metal footprint values (2010-2013) showed high footprint values for HH3, followed by HH2, HH4, HH5 and HH>5. The plastic footprint showed maximum value for HH>5, followed by HH2, HH3, HH4 and HH5.

Yearly Variations with respect to Household Income

The variations based on household income in the quantity of waste generation showed that all the wastes except plastic waste show significance in all the years (2010-2013). The plastic waste generation showed significance only in the base year (2010). The analysis showed that the paper, glass and metal waste generation (2010) showed their maximum for samples with household income 10K-15K(HHIC), followed by above 20K(HHIE), 15K-20K (HHID), 5K-10K(HHIB) and less than 5K(HHIA). For the years (2011-2013) the generation of paper waste showed proportional increase to the household income. The glass waste generation (2011-2013) showed their maximum for HHIE followed by HHIB, HHIC, HHID and HHIA. The metal waste generation showed their maximum for HHIE followed by HHIC, HHIB, HHID and HHIA. The organic waste generation (2011 – 2013) showed high values for HHIC followed by the HHIE, HHIB, HHID and HHIA. The plastic waste generation (2011-2013) showed high value for HHIC followed by HHIE, HHIB, HHIA and HHID. All the footprint values of wastes except for paper and plastic, showed significance in all the years (2010-2013). The paper and plastic footprint values show significant variations only in the base year (2010). Paper footprint (2010) is highest for the HHIB followed by HHIE, HHID, HHIC and HHIA. Glass and metal footprint (2010) is highest for HHIC followed by HHIE, HHIB, HHID and HHIA. Organic footprint (2010) is highest for HHIB followed HHIC, HHI5, HHIA and HHID. Plastic footprint (2010) is highest for HHIA followed by HHIE, HHIB, HHID and HHIC. Paper footprint (2011-2013) is maximum for HHIE followed by HHIB, HHID, HHIC and HHIA. Glass and organic footprint (2011-2013) showed maximum for HHIC followed by HHIB, HHIE, HHIA and HHID. Metal footprint (2011-2013) is highest for HHIC followed by HHIB, HHIE, HHID and HHIA. Plastic footprint (2011-2013) showed maximum for HHID followed by the groups HHIA, HHIB, HHIE and HHIC.

Yearly Variations with respect to Type of Waste Disposal

The variations based on the waste disposal method adopted showed that the metal and organic waste (2010) and the glass waste (2011-2013) generation showed significance. Glass waste generation (2011-2013) and organic waste generation (2010) in the houses which depends on community level waste disposal (CLWD) is more when compared to houses which opt for household level waste disposal (HLWD). The paper, metal, organic footprint values (2010-2013) and plastic footprint values (2010) showed more in CLWD than houses with HLWD. The reason for this can be put to the attitude of the people. If people are disposing in the CLWD methods, they are not bothered about the quantity of waste generation because they have the notion that the authorities responsible for the CLWD methods will dispose the waste. But people who opt for HLWD methods tend to reduce the quantity of waste generation as they are themselves responsible for the disposal and related problems.

Yearly Variations with respect to Housing Unit

The waste generation trend and footprint variations with respect to the type of housing unit showed no significant variation of means except for paper and metal waste generation (2010) and organic waste generation (2011-2013); glass (2010) and metal and organic footprint values (2010-2013).

For paper waste in 2010, the row housing units (RHU) generated more waste followed by houses in individual plots (HIP), low rise buildings (LRB) and high rise buildings (HRB). The metal waste generation (2010) is more for LRB, followed by RHU, HIP and HRB. The amount of organic waste tend to get generate more in HRB, followed by samples in RHU, LRB and HIP. The paper footprint is more for HIP, followed by LRB, RHU and HRB. The metal footprint values, organic and plastic footprint values show the same trend of glass footprint. The plastic footprint is more for HIP, followed by LRB, RHU and HRB.

Yearly Variations with respect to Ownership

The variations based on ownership details of the houses in the quantity of waste generation and footprint values showed that the variations are not highly significant in the type of waste and the footprint values except for paper (2010), metal (2010), plastic waste (2011-2013), paper footprint (2010) and metal footprint values (2010 -2013).

The paper waste (2010) is more in individual owned buildings (IOBs) followed by builder owned buildings (BOBs) and government owned buildings (GOBs). The metal waste generation (2010) is more for GOBs followed by IOBs and builder owned. The plastic waste generation (2011-2013) is more in BOBs followed by GOBs and IOBs. The paper footprint values (2010) are more for IOBs followed by BOBs and GOBs. The metal footprint is high in IOBs followed by GOBs and BOBs (2010-2013).

Analysis over the years

The analysis of waste footprint values of the households over the years were carried out for variables like household size, household income, type of housing unit, ownership for the different category of wastes and footprint values. The homogenous error testing of variance found insignificant for the other variables and therefore they were omitted. Then, the pooled analysis over the years were carried out for significant parameters/variables (household size, household income, type of housing unit and ownership) to check whether there is variation in the quantity of wastes and footprint values within year, between the parameter classes and within year and between parameter classes.

Variations Based on Household Size

Analysis of the variation of various components of wastes and footprint values with respect to household size over the years showed that within the year (2010-2013), the variations are significant for paper, glass and plastic wastes generation and for paper, metal, plastic footprint values. The average mean variations of the ANOVA analysis conducted for these variables over the years (2010-2013) showed that, the generation of paper waste is increasing from year to year. The temporal variations showed that the there is significant increase in the generation of glass waste up to the year 2012 (i.e. 0.61 kg in 2010 followed by 0.74 in 2011 and 0.90 in 2012) and then showed a decrease in the year 2013(0.69). The metal waste is also showing an increasing trend. The temporal variation in the paper footprint values over the years showed that, the footprint values were 2.86 hectares per capita in 2010 which has increased to 3.74 in 2011, then to 3.79 in 2012 and 4.18 in 2013. The metal footprint values also showed significant increase from 23.05 hectares per capita in 2010 to 33.67 hectares per capita in 2013.

The analysis also showed that there are significant mean variations in the generation of organic waste between the HH size classes, which is increasing with the HH size but showed a slight increase for the households with HH size three. The plastic footprint values has been on the increase from year to year which have increased from 2.67 hectares per capita in 2010 5.48 hectares per capita in 2013. The analysis showed that the there are fluctuations in the average mean values in the case of glass, organic and plastic waste generation. The paper footprint values show a decline among the household size classes.

Variations Based on Household Income

Analysis of the variation of various components of wastes and footprint values with respect to household size over the years showed that all categories of wastes and footprint values except metal and organic footprint values showed significant mean variations within year. All categories of wastes and footprint values show significant mean variations between HH size classes. But there are no significant mean variations in the variables within year and between HH size classes. All the variables except organic waste, paper footprint and plastic footprint values are showing increasing values up to the year 2012 and then show a decrease. The variations based on household income showed that the quantity of generation of paper waste is directly proportional to the household income up to the class 15K-20K and then decreases for the income class above 20K. The temporal variations in the amount of glass waste generation over the years showed that, the quantity of glass waste generation has been on the increase from year to year up to 2012 and then showed a decline. The temporal variations in the amount of metal waste generation over the years show that the quantity of metal waste generation has been on the increase up to 2012 and then showed a decline.

The quantity of organic waste generation has been on the increase from year to year. The variations based on household income showed that the plastic waste generation is highly flexible with income levels. The footprint values showed similar variations as that of their corresponding wastes.

Variation Based on Type of Housing Unit

Analysis of the variation of various components of wastes and footprint values with respect to the type of housing unit over the years showed that only paper waste, paper footprint and plastic footprint showed significant mean variations within year.

The mean variation showed that the paper waste generation increased from 0.23 kg/week/house in 2010 to 0.36 kg/week/house in 2013. The plastic footprint also showed similar variation (2.95 m^2/capita in 2010 to 5.76 m^2/capita in 2013). The paper footprint showed an increase from 2.92 m^2/capita in 2010 to 4.56 m^2/capita in 2012 and then showed a decline.

The analysis also showed that paper, glass, organic wastes and paper, glass, metal and plastic footprint values showed significant mean variations between types of housing units. The paper wastes showed more generation in row housing units followed by high rise buildings. Glass wastes and organic wastes showed high generation in high rise buildings. The paper footprint values are more in houses in individual plot. The glass and metal footprint values show highest values in low rise buildings. The plastic footprint is more in row housing units when compared to other type of housing units. And there are no significant mean variations in the variables within year and between housing unit classes.

Variation Based on Ownership

Analysis of the variation of various components of wastes and footprint values with respect to the type of ownership of the house over the years showed that only paper waste, paper footprint and glass footprint showed significant mean variations within year. The analysis also showed that paper, glass, metal, plastic wastes and paper, metal and organic footprint values showed significant mean variations between types of ownership classes. And there are no significant mean variations in the variables within year and between housing unit classes. The paper waste, paper footprint and glass footprint values are increasing over the years with respect to the ownership of the house. The paper waste generation is increasing from 0.21 kg/week/house (2010) to 0.32 kg/week/house (2011), 0.33 kg/week/house (2012) and 0.37 kg/week/house (2013). The paper footprint values showed an increase from 2.43 m^2/capita (2010) to 3.72 m^2/capita (2011), 3.98 m^2/capita (2012) and 4.12 m^2/capita (2013). The glass footprint values showed an increase from 2.22 m^2/capita (2010) to 3.51 m^2/capita (2011), 3.98 m^2/capita (2012) and 3.46 m^2/capita (2013).

The variations based on housing ownership in the quantity of generation of paper waste showed that the amount of paper waste generation is more in individual owned buildings (IOBs) followed by builder owned (BOBs) and government owned (GOBs). The amount of glass waste generation is also more for (GOBs) followed by (BOBs) and (IOBs). The amount of metal waste generated is more for (IOBs) followed by (GOBs) and (BOBs). The amount of plastic waste generated is more for (BOBs) followed by (GOBs) and (IOBs). The variations based on ownership classes showed that the paper footprint is high for (IOBs) followed by (BOBs) and (GOBs). The metal footprint is more for (IOBs) followed by (GOBs) and (BOBs) The organic footprint is also more for (IOBs) followed by (GOBs) and (BOBs) the total footprint is more for (IOBs) followed by (GOBs) and (BOBs).

CONCLUSION

The statistical analysis of the waste footprint of the city concludes that, the concept of waste footprint can be used as a valuable tool for assessing the impact of waste generation and its disposal with respect to different variables affecting city population. This can be used as a baseline for framing policies and strategies for sustainable solid waste management in the residential areas of Kochi city.

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