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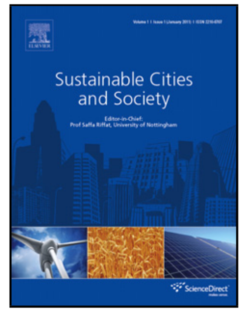

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Household solid waste generation and composition in different family size and socio-economic groups: a case study

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Abstract

The household waste (HW) constitutes an important fraction in municipal solid waste (MSW). The composition of HW is an important factor in design an effective solid waste management plan for city. The aim of study was to estimate the quantity and quality of HW in terms of socio-economic groups and family size in the Dehradun city, India. A total of 144 households were selected from 11 major blocks of the city and HW quantification and characterization was analyzed for different blocks/colonies. The HW generation rates in the city ranged from 24.5 – 4147.1 g/day. The average HW quantity in households was estimated: 267.17 g/day (SD = 38.13, n = 144). The food/kitchen waste was the major constituent (≥ 80% of total weight) of HW in city followed by polythene and plastic (≈7%), paper (≈6%), cardboard (≈2%) glass/ceramic scrap (≈1%) and other miscellaneous (e.g. cloths, silt, dirt, rubber; all ≈4%). The HW quantity and composition varied significantly among different socio-economic groups in the city. The maximum HW generation rate was in higher- followed by middle- and lower-income group. The HW generation showed positive correlation with family size (r_{xy} = 0.348, p< 0.01). On the basis of obtained data sets, it is concluded that HW can be a potential resource for energy and manure production if proper waste management system is designed for the city.

***Keywords*:** Municipal solid waste, Waste recycling, Composting, Food waste, Waste generation in developing countries

1 Introduction

The household waste (HW) is an important part of the municipal solid waste (MSW) stream (Dangi et al., 2008, 2011). The quantity of MSW has been increased several times in urban centres of developing countries during last few decades. The high population growth in urban areas due to rural migrants, changing life style of urban population, economical growth, social improvements in societal groups in urban areas etc. the important drivers of this enormous growth in MSW quantity in developing cities of Asia and Africa. The data of quantity as well as quality of HW clearly gives an idea about sustainability of the developing urban centres. HW waste also indicates the socio-economical conditions of the households and urban society. There is an interesting relationship between buying capacity of the urban population and amount of the domestic waste generated (Ojeda-Benitez et al., 2003). Few earlier studies have suggested a close interrelationship between waste quantity/quality and socioeconomic status of households in developing countries (Sujauddin et al., 2008; Qu et al., 2009; Thanh et al., 2010). An increase in income can change the consumption patterns of households which results in changed composition and quantities of HW (Ogwueleka, 2013).

The quantification and characterization of HW should be done in order to design an effective waste collection and waste management plan for the residential block of the city. HW is a heterogeneous type of stuff which contains a variety of wastes of different chemical and biological nature (e.g., biodegradable, non-biodegradable, biologically contaminated, hazardous type, solid, semi-solid, inert etc.). So such stuff needs close attentions while designing the major waste management processes (handling, segregation, transportation and treatment) to minimize the environmental and occupational health issues related to the whole waste management mechanism. For that a detailed characterization of HW is essentially needed in order to develop an effective waste management plan for the urban residential localities of the city. The solid waste management plan includes all activities that seek to minimise the health, environmental and aesthetic impacts of solid wastes.

Unscientific disposal practices leave waste unattended at the disposal sites which attract birds, rodents, fleas etc. to the waste and creates unhygienic conditions like, odour; release of air borne pathogens; greenhouse gases (GHGs) emissions; breeding of disease vectors (e.g., flies, mosquitoes, cockroaches, rats, and other pests) etc. in the surroundings. The uncollected waste piles left in the streets, blocking drainage channels, waste dumped in the watercourses etc. are the major cause of public health risk. The uncontrolled waste disposal can threaten urban surface water resources and pose significant environmental health risks in residence those living nearby to it (Bhuiyan 2010).

The composition of HW also reveals the trends of waste reuse/recycling habit which is in practice as informal act in many parts of the developing counties. In this practice, few wastes articles of economical/reusable/recyclable values (e.g., cardboard, plastic, empty liquor bottles, metal/tin containers, old newspaper scrap) are separated by the households (mainly middle-income and low-income groups of the society) for further sell to interim buyers (*Pheriwalas*), street hawkers or junk shops. In this way, such practice also affects the original composition of the HW to be received at community waste disposal and collections points. The composition of HW may also reflect the psychology of the local residents which are major actors of the MSW system of any city. In order to examine the role of households in MSW production and handling practices, a study on HW characterization may be topic of interest for city planners policy makers and waste handling agencies in the city.

The Dehradun is one of the fastest growing urban centres in India. It is a one of the densely populated hill station in the country, located in foothills of Himalaya with enormous natural beauty and vegetations. As per last census report the total population of the Dehradun city is around 0.58 million (India Census 2011). During 1981 to 1991 the human population growth rate was the highest in the India during a decade. This was due to massive migration of people from other areas after declaration of Dehradun as capital of newly carved State Uttarakhand in India. However, other than permanent residents city also has a large floating population of tourists, commuters and business travellers. Tourist arrivals in 2004 and 2005 were 1.25 and 1.26 million, respectively. The migration from remote areas in the city is creating unplanned urbanization and slum development, and these areas produce a lot of unmanageable quantities of solid wastes.

In order to design a decentralized waste handling and management system at community level in the city the characterization of HW need to be investigated for the local needs. The infrastructure availability, socio-economical status of households, social awareness level, environmental education and training etc. are the important drivers for designing a decentralized HW management system in urban centres. Therefore, the aim of present study was to investigate on few issues: HW quantification and composition in the city, assessment of HW composition and generation rate in different socio-economic groups of the society in the city, and analyzing the possibility of utilizing HW as valuable resource for energy and sustainable urban development plan. The information of city's HW characteristics can be further used for designing a community-based integrated solid waste management plan for the urban centres.

2 Materials and methods

2.1 Study site

Dehradun city is located in the foothills of Shivalik mountain ranges, Uttarakhand State, India. The city has an area of about 67 Sq. Km. Dehradun is the administrative centre and the interim capital of the State Uttarakhand. The Himalayas borders the Dehradun in north, the Shivalik forest range in south, the sacred river Ganga in east and the river Yamuna in west. The city is surrounded by river Song on the east and river Tons in west. The climate of this part is generally temperate and it varies greatly from tropical to severe cold depending upon the altitude of the area. The area receives an average annual rainfall of 2073.3 mm. Most of the annual rainfall in the district is received during the months from June to September, July and August being rainiest. The winter months are colder with the maximum and minimum temperatures touching 23.4°C and 5.2° C respectively.

2.2 Sampling methodology and data collections

The sampling procedure of HW was designed after in-house planning and workout on patterns of residential settlements in the city. To collect the information on HW quantity and quality, the survey on HW was conducted at mass level for about three months (March to May 2011) in the city. After analyzing the city's settlement plan and demographical data the areas for survey and HW sample collection were identified in the city. A total of 11 different blocks/colonies in the city were selected and HW samples were collected from 144 houses from different blocks after taking prior consent from household to cooperate in the HW collection project. The sampling was designed by taking care of covering almost all localities of a colony/block for waste collection program. A detailed questionnaire was prepared for collection of baseline data of sampling locations/points like; number of residents per sampled household, total income of the household, HW management, segregation, recycling practices and disposal options. For assessment of socio-economic status of the household the information about annual income of the household, house/ building structure, locality of colony, available facilities in house, type of vehicles in house, other luxury facilities in houses etc. was also collected. On the basis of the collected datasets the participatory households in project were then classified into three sub-categories: low income, middle income and high income group.

After initial workout, the HW sampling programme was started. The HW was collected from pre-fixed sampling points. For that a large sized polythene bag of 10 kg capacity was provided by the research team to households and instruction was given to store all kinds of waste generated from house during 24-h period. After the duration the garbage bags were collected from household and brought to the laboratory for further screening and analysis. In laboratory, garbage bags were emptied and weight of total garbage collected was measured dry weigh-basis. After weighing, the garbage was hand sorted to separate the different fractions of the garbage and weighted further item wise. The results of different factions of garbage were expressed in percent of the total HW.

The household garbage was diving into following main categories:

- Kitchen waste/food waste – Peeling waste, discarded vegetables, food waste, discarded food, seeds etc.
- Paper – paper scrapes, packing papers, discarded papers from students bags etc.
- Plastic & polythene bags – plastic articles, polythene and other items made of primarily plastic
- Glass and ceramic scrap– scrape of glass, bottles, glass containers, broken kitchen articles made of glass and ceramics etc.
- Cardboards – non-recyclable paper, cardboards, cartons, etc.
- Others – metallic items, can, rubber, textile, leather, jars of metal, soiled paper, wood, saw dust, leaf litter, garden pruning, dirt and other inert material

After screening the garbage was then disposed safely to the waste collection facilities of the University campus for further disposing of the garbage.

2.3 Statistical Analysis

An analysis of variance (ANOVA) was calculated in order to find out significant difference regarding the garbage generation rate among different households and different income groups. Data were subjected for descriptive statistical analysis for production a range of statistical parameters like median, standard deviation, range, skewness and kurtosis, variance and Stem-and-Leaf Plots. SPSS® statistical package (Window Version 16.0) was used for data analysis. All statements reported in this study are at the $p < 0.05$ levels. Relationship between numbers of dwelling per household and total waste generation was calculated using simple correlation matrix.

3 Results and Discussion:

3.1 Current household waste disposal practices

The Dehradun city is divided into several subzones/colonies as per local municipal record. A total of 11 different blocks/colonies were selected to study the HW characterization. The demographical data of these areas are presented in Table 1. As per the data of census (Census, 2001), the population of theses blocks/colonies varies from 7,677 – 17,028. The collection, transportation and management of MSW of the city is mainly governed by the local municipal corporation. In some areas few NGOs and non-profit organizations are also assisting the municipal people in HW collection and transportation services. The facilities and services at secondary MSW collection points have been provided by the municipality in these areas. The demographic data and details of existing secondary waste storage facilities in these areas are described in Table 1. The secondary waste collection system is comprised of open, masonry, concrete and metallic containers. For HW collection the fixed-point communal containers (Plate 1A) are established in the blocks/colonies. The collected HW is then further transported to the local MSW disposal site of the city. The number of community containers in each block/colony is fixed on the basis of the population and number of houses in the block/colony. In areas where community containers are not established the MSW is collected through tractor-trailer system. In few areas of the blocks the people have to dispose their HW on roadsides, open spaces, wasteland etc. just to avoid necessary walk to dump garbage in the fixed community containers, located slightly far from the residential locations. Although, the municipality people frequently (after 1 – 2 weeks interval) visits to the secondary community waste disposal points to collect the garbage but sometime delay in the process forces people to dispose their HW on the ground around a fully-loaded community container. The fractions of HW like discarded food or vegetable wastes are sometime removed by the scavengers (street dogs, cows, birds etc.) from the community containers. Rag pickers also picks recyclable (polythene bags, plastic scrap, polythene bottles, metals, paper, glass etc.) waste articles/items from the community containers which has been appeared as major problem for municipality people in proper waste collection process. Rag pickers sometimes remove the garbage from community containers to sort-out recyclable items from MSW composites. Such practices have been creating unnecessary burdens for municipality people who are involve in MSW collection and transportation process.

Insert Table 1& Plate 1

There is no formal HW segregation, resource recovery and composting facility is available in the city. The MSW is mainly dumped at waste trench ground located at Daandalakhon in the city. The non-segregated and mixed type of MSW is transported directly to the waste disposal point (Plate 1). The major practice for MSW management in the city is landfilling. The size of waste trench ground (landfill) is about 3.7 hectare. Geographically, the landfill site is located between N 30° 20' 32.0" and E 078° 04' 38.5". It is a newly established landfill site of the city working since November 2002. The base of this landfill sites is a wide shallow depression, lined by large rounded pebbles. About 10 frontend loaders work every day to dispose the city's garbage. The disposed MSW is then settled by JCB which usually adjust about 100 tonnes waste per day.

3.2 Household waste generation rate

There was statistically significant difference among different locations for total HW solids generation rate (ANOVA: F= 7.635, $p < 0.001$). The HW generation rate was in the ranges of 24.5 – 4147.1 g/day in different locations of the city. The average HW generation was 267.17 (SD = 38.13, n = 144) in the city. The total quantity of household waste ranged 1.5 – 0.22 MT/day in different areas of the city. The different urban zones of the city showed drastic variations for total HW generation trends. The per capita HW generation was calculated by dividing the total waste produced with the number of people living in that household that day (Dangi et al., 2011). The data sets were then used for plotting a histogram of waste generation pattern in the city using statistical tool. The histogram clearly suggests that in majority of cases the total waste generation/day/ household was < 260 g (Fig. 1).

Insert Fig. 1

There was significant variations among household for per capita waste generation rate (g/capita/day). The mean household waste generation rate was 55.12 with 78.97 corresponding standard deviation (SD). The statistical analysis of waste generation in the city is described in Table 2. It indicates the values of range, variance, skewness and kurtosis (685.06, 6236.18, 5.377 and 38.04, respectively). The median value 119.40 was lower than the mean of total waste generation (Table 2).

Insert Table 2

The waste generation rate ranged between 19.6 g/capita/day to 115.8 g/capita/day. The HW is generally lower in developing countries than developed nations mainly due to the segregation of recyclable items from HWs. It was noted that few reusable/recyclable items like: newspapers, cardboards, woody items, plastic containers, empty beverage and wine bottles, metal containers etc. are usually separated by the households for the purpose of selling to street hawkers (*Pheriwalas*) or waste/ scrape shopkeepers in the market. This informal waste recycling market is not only provides business and employment opportunities to poor urban people but at the same time also plays an important role in reducing the quantity of total waste received at end disposal points. The information on HW production in Indian cities is not available abundantly but frequent reports on MSW production and its composition are available in published literature. Since, sources other than households contributes more than 50 % of the total solid waste generated in the city which includes: street sweeping, urban garden/park waste, market waste, hospital waste, demolition and construction waste, industrial wastes and city sludge.

There has been significant increase in the quantity of MSW generated in India over the last few decades. This is largely a result of repaid population growth in the country. The daily per capita generation of MSW in India ranges from about 100 g in small towns to 500 g in large towns. The solid waste generated in Indian cities has increased from 6 million towns in 1947 to 48 million tonnes in 1997 and is expected to increase to 300 million tonnes per annum by 2007(CPCB-2000). Rapid urbanization and unplanned township has created the major problem of solid waste collection, segregation and engineered waste management practices. The problems associated with proper waste management system arise due to the unsustainable consumption system in developing countries. The migration of population from neighboring rural area to urban township leads to rise of problems of MSW disposal and its proper collection. There was drastic variation among different sampling blocks/colonies for daily per capita HW generation rates. In India, the waste generation ranges from 100 g in small towns to 500 g per capita per day in large cities. The waste generation per capita mainly depends upon the lifestyle, culture, occupations, income and social status. In this study the waste generation/capita/day was slightly lower than average as reported by CPCB (2004) for other cities.

3.2 Household waste composition and its possible utilization

The composition of HW is directly affected by a variety of factors: socio-economic status of households, cultural conditions, food habits, season, geographical locations etc. The composition of HW in the present study sites are described in Table 3.

Insert Table 3

In terms of the quantity, the food wastes have been appeared as the major faction of the HW than others. The quantity of all the major five items in HW (*viz*. paper, plastic & polythene bags, woody items, glass/ceramics, cardboards/cartons and miscellaneous items) recorded during the survey varied significantly among different locations of the city. The food/kitchen waste was found to be the major fraction (79.8 %) fraction in HW followed by plastic & polythene bags (7.58 %), paper

(5.88 %), miscellaneous items (textiles, rubber, metal scrap, dirt and silt, wood, soiled paper etc. = 4.39 %), cardboards (1.68 %) and glass-ceramics (0.64 %) (Fig. 2).

Insert Fig. 2

There was statistically significant variations among different locations (blocks/colonies) of the city for HW composition: paper (3 – 10 %), plastic & polythene bags (4 – 15 %), food/kitchen waste (69 – 87 %), glass & ceramic scrape (0 – 2 %), cardboards (0 – 7 %) and other miscellaneous items (0 – 10 %). It is clear from observation that, in all blocks of the city, the food/vegetable waste was the main constituents of HW followed by, plastic/polythene bags, paper, cardboards, others and glass-ceramic scraps. It is to be mentioned here that hazardous waste contents in HW was comparatively lower as compared to cities of the developed countries. The majority of hazardous component (as included in miscellaneous waste faction of HW) in HW consists of dry cell, batteries, computer CD, empty containers of household insecticides and pesticides etc. The fraction of such waste in HW was in the ranges of 0 – 3.9 % of the total volume of the wastes. The segregation of recyclable items and reselling of electronic and electrical equipments, as whole or in parts, at household level is the major cause of low volume of hazardous items in HW in the city.

The block-wise difference in HW composition could be mainly due to the economic structure, social rank and hosing location in the city. Although, few very common items of HW (e.g. glass containers, metal items, fresh news papers & books, electronic items) were wanting from collected samples from different locations of the city which clearly indicates the role of informal waste recycling/reuse practices at households level in the city. It was also observed during the waste sampling operation that the local residents isolates reusable/recyclable items from the HW and sells directly to interim waste buyers (*Pheriwala*) or to local small vendors.

The statistical analysis results (mean, standard deviation, range, variance, skewness and kurtosis) are presented in Table 3. Although standard deviation was lower than mean values of each waste fraction, but values of variance were higher than mean for all components of the HWs. The food/kitchen waste in HW, as recorded in this study, is comparable with several other cities of developing world: 69.3 % - Beijing, China (Qu et al., 2009), 62.0 % - Chittagong, Bangladesh (Sujauddin et al., 2008), 71 % - Kathmandu, Nepal (Dangi et al., 2011), 77 – 78 % - Mekong Delta, Vietnam (Thanh et al., 2010), 76.3 % Damaturu, Nigeria (Babalola et al., 2010). Results clearly suggest that food/kitchen waste was the major component of HW in the city. In developing countries the majority of the rural as well as urban population cooks their daily meals in house kitchens and usually therefore; the food waste (wastes from kitchen) is the major component of the HWs. According to Gupta et al. (1998), the solid waste composition in the urban centers depends on a wide range of factors such as habitats, culture tradition, lifestyle, climate and income etc. According to a report published by TERI (2002), the biodegradable is the major proportion of municipal waste (38.6 %) followed by inert materials (stones, bricks, ashes, etc.: 34.7 %), non-biodegradable (leather, rubber, bones, and synthetic material, 13.9 %), plastic (6 %), paper (5.6 %) and glass and crockery (1.0 %). The relative percentage of organic waste in MSW is generally increasing with the decreasing socio-economic status; so rural households generate more organic waste than urban households.

The biodegradable and non-biodegradable fraction in HW was also estimated in this study. Results thus clearly indicate that the majority of fractions of HW were of biodegradable (paper, food/kitchen waste, leaf litter etc.) nature (ranging 86.7 – 96.1 % of the total) and rest was of non-biodegradable (3.9 – 15.4 % of the total) category. It is clear that a large part of HW in the city is of compostable nature and that can be used as substrate or bulky material for preparation of compost at large-scale. Few earlier reports have also indicated that in the majority of urban centres of the developing countries the compostable material is the main constituent of HW (Ojeda-Benitez et al., 2003; Sujauddin et al., 2008; Thanh et al., 2010; Dangi et al., 2011). According to indiastat report (indiastate.com, 2009) the MSW generated in the Indian cities have the high proportion of the biodegradable items (> 40 – 60 % of the total) which can be utilized effectively for composting operation. But majority of such waste is either dumped in landfill sites or consumed by scavenges.

On the other hand the percentage of recyclable items in HW remains low because of screening of HW by the rag pickers from the houses (indiastat.com, 2009). The composition of HW of sub-urban and rural locations is completely different than the modern urban centers and metropolitan cities of developing countries. In majority of sub-urban centers and rural areas the waste articles of reusable and/or recyclable importance are usually segregated by households prior to disposing house garbage at secondary waste collection facility points.

The HWs mainly contains easily biodegradable substances which in general produces intolerable odour, volatile organic compounds, noxious green house gases (GHGs) etc. during decomposition. The possible solution of this problem seems the utility of HWs in composting or biogas production at community- or municipal-scale. Currently, there is no formal waste treatment facility is established in the city. Therefore, such wastes can be managed effectively through resource generation operations (e.g. anaerobic biogas generation, land applications etc.). Traditionally, the aerobic composting has been recommended as sound option to convert negligible organic waste resources into added-value product, i.e. manure. The composting is a biooxidative process involving mineralization and partial humification of the organic waste stuffs (Zucconi and de Bertoldi, 1987), mainly catalyzed by detritus decomposers (e.g. bacteria, fungi and other microorganisms, microarthropods etc.). The final product of this process is a stabilized material, free of phytotoxicity and pathogens. Composting is a useful and economically viable option to convert organic waste solids into valuable organic matter for use as an organic amendment in cultivable soils (Couth and Trois 2012; MacCready et al. 2013). However, the major drawback of composting of HWs or MSW in the urban centers is the chemical quality of the end materials. Due to mixed type collection of HW (at primary and secondary waste collections points) the waste is contaminated with several types of hazardous and toxic substances. Therefore, HW in majority of cities of developing countries appears to be a heterogeneous type of waste mixtures having biological as well as chemical contaminations. Saha et al. (2010) have reviewed the quality of the compost prepared at composting facility centers at 29 different cities in India. The compost is being prepared from source segregated or mixed MSWs in these cities. A total of 30, 63, 14 and 77 % samples of composted MSW showed the higher ranges of Cu, Pb, Ni and Cr, respectively than the regulatory limits. As per the scheme, the majority of the compost samples did not belong to any marketable classes and hence, have been found unsuitable for any kind of use. In conclusion, this is a fundamental problem in utilizing HWs in compost manufacturing. However, anaerobic digestion and biogas production seems sound alternate to avoid these problems. Utilizing HWs in biogas production can solve twofold issues: waste disposal and energy crisis in such urban centers. The limitations of this operation may be: the high operation/maintenance costs and technical problems (e.g. consistent quality of HWs, presence of toxic substances, particle size, moisture contents, inert material presence etc.) while handling the wastes.

3.3 Waste generation in different socio- economic group and family size

Statistically, there was no significant difference among all the three socio-economic groups of the society for total waste production rate (waste in g/capita/month) (ANOVA, $F = 0.122$, $p = 0.887$). The composition of waste collected from different sector of the society is described in Table 4. In all income groups the food/kitchen waste was the dominant component (74.5 – 80.7 % of the total volume/weight) in HWs followed by polythene and plastics and papers waste. In the high-income group overall composition of HW was: food/kitchen waste (80.7 %), paper waste (5.17 %), plastic and polythene (7.13 %), glass scrape (0.10 %), non-recyclable paper and cardboards (1.38 %), and miscellaneous items (5.47 %). In the middle-income group the composition was: food/kitchen waste (74.5 %), paper waste (7.97 %), plastic and polythene (8.69 %), glass scrape (0.89 %), non-recyclable paper and cardboards (2.22 %), and miscellaneous items (5.68 %). The low income-group of the society showed slight variations for HW composition: food/kitchen waste (83.54 %), paper waste (3.96 %), plastic and polythene (7.66 %), glass scrape (1.03 %), non-recyclable paper and cardboards (1.42 %), and miscellaneous items (2.36 %). A report of Municipal Corporation of Delhi (MCD, 2004) has also suggested the difference between income groups of the society in terms of quantity and quality of waste generated from households. The data analysis suggested food/kitchen waste as the major component (58.4 – 76. 6 % of the total waste) in HWs of all the three socio-economic groups of the society which was about. The other waste includes recyclable: 15.7 % in low income group, 21.2 5 in middle income group and 23.1 % in the high income group.

Insert Table 4

As the economy grows and the population becomes more urbanized, the substantial increase in the use of paper and paper packaging is probably the most obvious change. The composition of MSW varies according to the cultural habits and economic status of the residents, urban structure, density of population, extent of commercial activity and climate. Information and data on physical components of the waste stream are important in the selection and operation of equipment and facilities, in assessing the feasibility of energy and resource recovery and in the design of a final disposal facility (Tchobanoglous et al., 1993). Also, Sujauddin et al. (2008) concluded that the physical component of HW is always important for adaptation of further management practices. The high organic content indicates the necessity for frequent collection and removal, as well as having a good prospect of organic waste recycling through composting.

The role of family size in HW generation rate was also calculated during this study. The majority of households are represented by 5 to 6 persons/households (Fig. 3) in the city. There were great variations among households with different family size for the quantity of HW generated. The maximum average quantity of HW was 680.25 ± 564.19 g/pc/day in household with 8 family members followed by 342.9 ± 314.49 g/pc/day in household with 6 family members, 240.74 ± 381.67 g/pc/day in household with 5 family members, 236.13 ± 114.05 g/pc/day in household with 7 family members, 136.97 ± 118.0 g/pc/day in household with 4 family members and 129.16 ± 118.75 g/pc/day in household with 2 family members (Fig. 4).

Insert Fig. 3 & 4

The result of statistical analysis of HW generation in different family size is described in Table 5. It is clear from the data that the value of variance was greater than the mean in the all sub-sets of family size. The HW quantity in per family size category was the maximum in household with 5 family members (30 – 1993.0 g/day). However, the difference between household with family size of 2 and 7 was not statistically: 339.5 and 346.6 g/day/day, respectively. The generation of HW was found to be positively correlated with family size (r_{xy} = 0.348, p< 0.01). A non-parametric Spearman's correlation also showed significant relationships between family size and waste generation (ρ = 0.480, p< 0.01). The results are corroborated with the finding of Dangi et al. (2011) and Sujauddin et al. (2008) who have also recorded a strong correlation between waste generation rate and the family size in their studies.

Insert Table 5

4. Conclusions

This work provides an opportunity to study about solid waste generated from households of the Dehradun city of Uttarakhand, India. Results thus, clearly suggest that the biodegradable stuff was the major component in HW; mainly comprised of vegetable/food waste and paper waste. The fraction of reusable/recyclable items in HW was comparatively low than MSW composition of other metro/small cities of the India. It could be attributed due to in-house screening of recyclable/reusable waste articles from HWs. Thus, the HW which reaches to secondary waste collection points not has a good amount of such items of reusable or sellable values (e.g. plastic, metals, glass containers, cardboards, fresh paper etc.). The study also revealed that inadequate facilities at secondary waste collection points in majority of blocks/colonies in the city have been creating several health and environmental pollution issues. The majority of components of HW is of biodegradable nature thus, can be efficiently for generation of added-value products (e.g. compost/manure, biogas, digestive slurry etc.) for sustainable urban habitat development and land restoration programme.

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Caption of Figures and Tables

Plate 1 (A) community containers, (B) unloading of community continers and landfill site, (C) landfill site overview, and (D) MSW deposition in landfill site of the city

Fig. 1 (A) – Frequency distribution of :(A) household waste generation/household (g/day) and (B) waste generation rate (g/capita/day)

Fig. 2 Compostition (based upon average value) of household waste in the city.

Fig. 3 Frequency distribution of numbers of residents /household

Fig. 4 HW waste generation patterns in terms of numbers of residents /household

Table 1 Population, area and secondary storage facilities in different parts of the city.

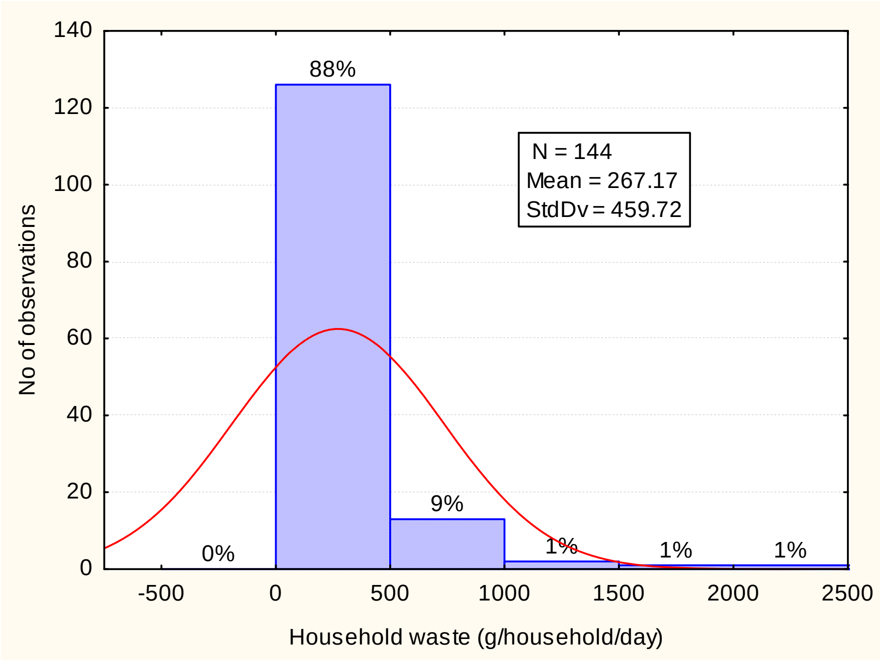
Table 2 Statistical analysis results of waste volume and waste generation rate in the city

Table 3 Household waste composition (n =144 households) and statistical analysis data

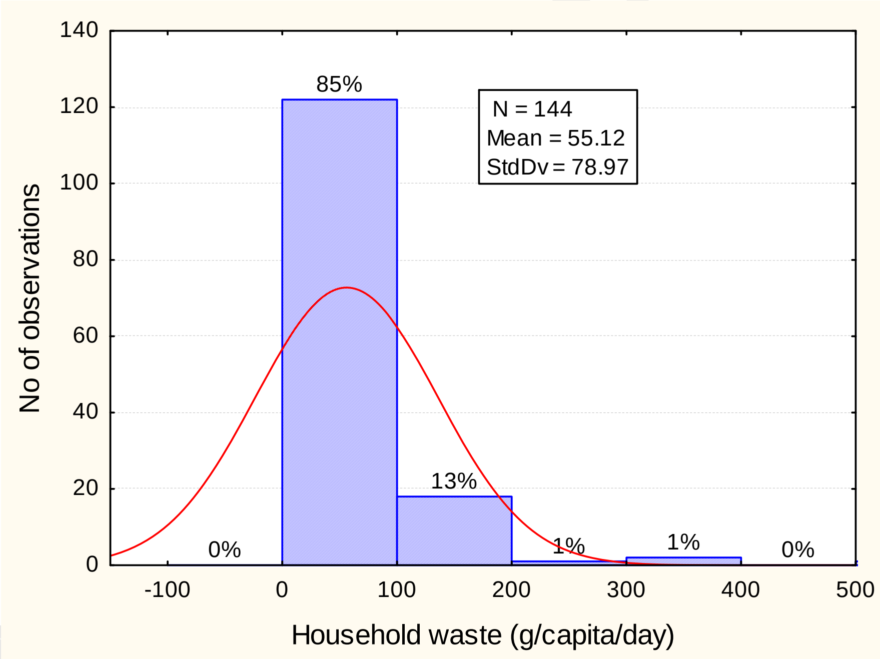
Table 4 - Household waster composition in different socio-economic groups in the city

Table 5 – Waste generation rate in different family size of households for the city

Plate 1 (A) community containers, (B) unloading of community continers and landfill site, (C) landfill site overview, and (D) MSW deposition in landfill site of the city

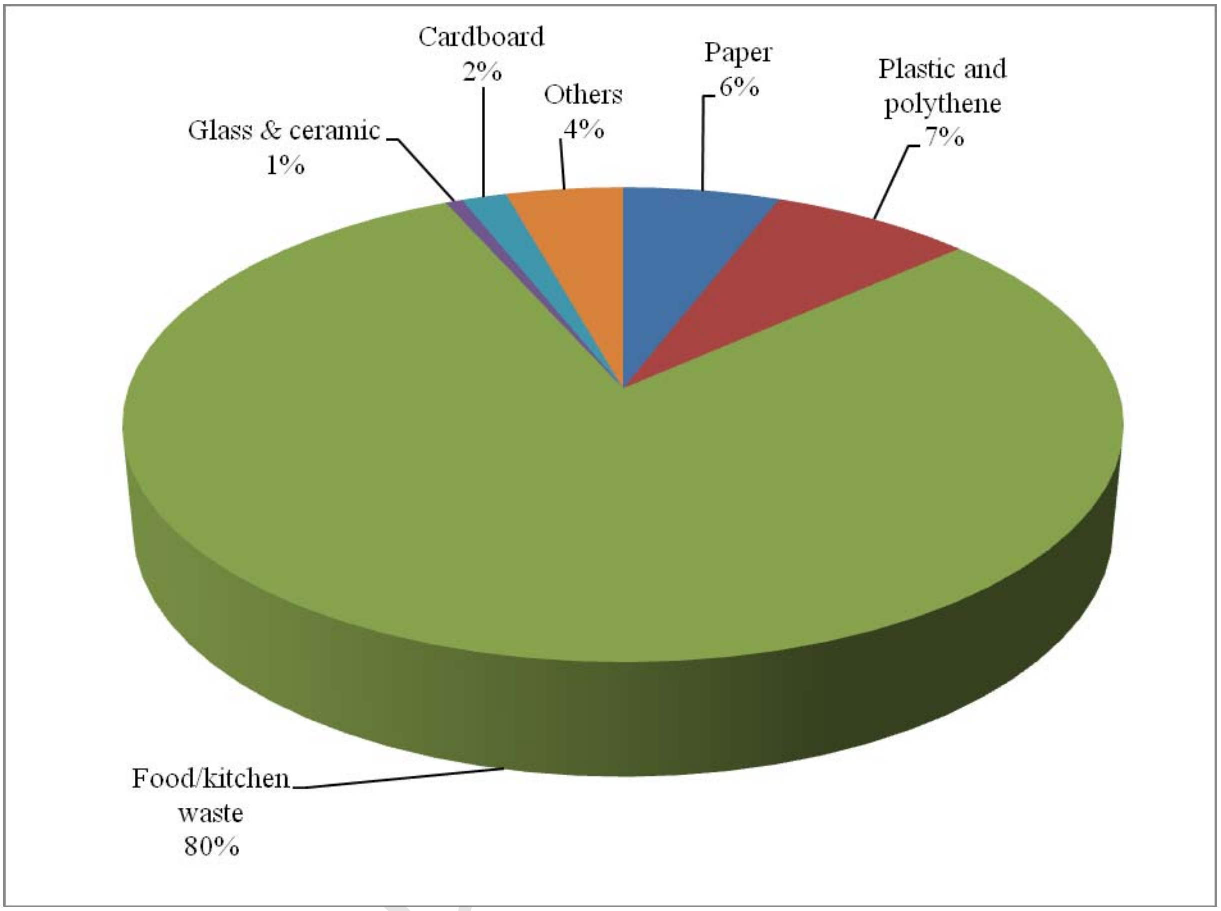


A



B

Fig. 1 (A) – Frequency distribution of :(A) household waste generation/household (g/day) and (B) waste generation rate (g/capita/day)



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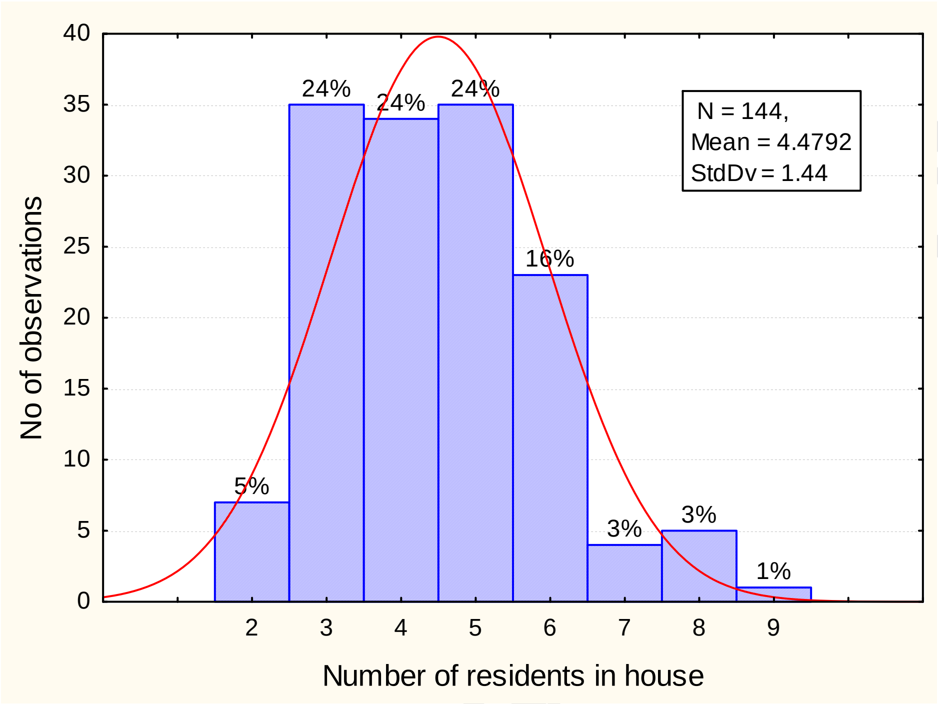

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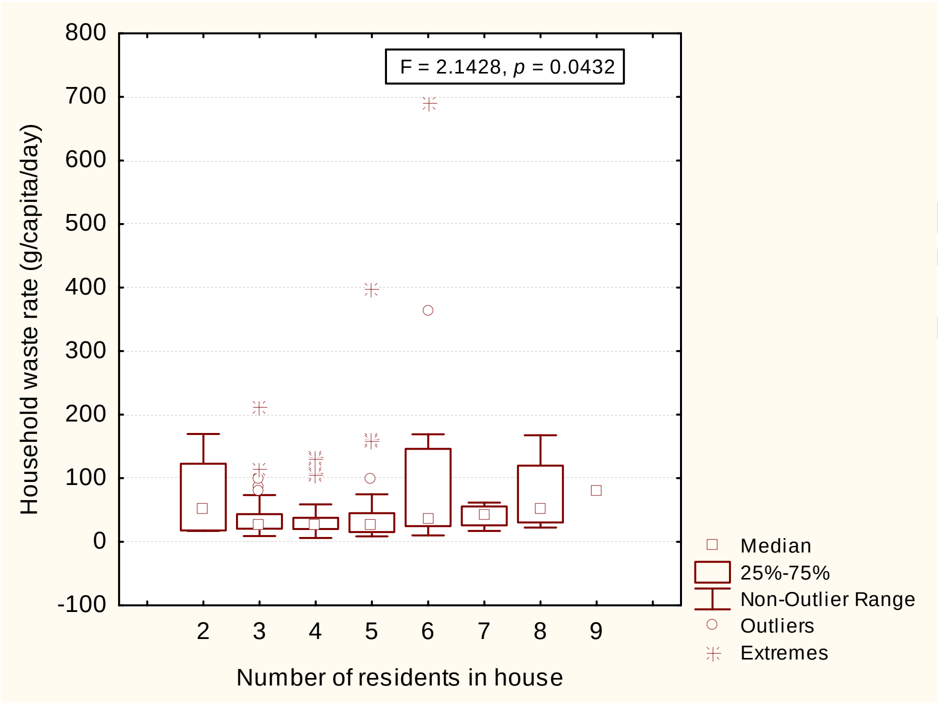

Fig. 4 HW waste generation patterns in terms of numbers of residents /household

Table 1 Population, area and secondary storage facilities in different parts of the city.

Location	Pop as per census 2001	Area (Km^2)	Secondary waste storage facility available				
			Open	Masonry	Concrete	Metallic	Total
Nala Pani	11389	5.38	4	Nil	4	7	14
D.L. Road	9178	0.33	3	1	Nil	4	8
Rishi Nagar	8686	4.30	2	Nil	2	Nil	4
Karanpur	8022	0.90	Nil	Nil	4	2	6
Adhoiwala	17028	2.43	4	2	1	1	8
Kewel Vihar	8403	0.98	Nil	Nil	Nil	3	3
Dharampur	9913	0.39	2	4	2	Nil	8
Vijay Nagar	8244	1.68	Nil	Nil	Nil	3	3
M.D.D.A Colony	18023	4.41	4	Nil	Nil	12	16
Sumanpuri	8118	0.40	2	Nil	Nil	2	4
Vikas lok	7670	0.24	2	Nil	Nil	1	3

Table 2 Statistical analysis results of waste volume and waste generation rate in the city

Parameters	Waste generation/households (g/day)	Waste generation rate (g/cap/day)
Mean	267.17 g	55.12
SD	38.13	6.58
Range	4122.6	685.06
Variance	211343.75	6236.18
Minimum	24.5	6.13
Maximum	4147.1	691.18
Skewness	5.377	4.896
Kurtosis	38.04	32.32

Table 3 Household waste composition (n =144 households) and statistical analysis data

Waste item in HW	Mean	SD	Range	Variance	Skewness	Kurtosis
Paper waste	14.15	2.03	0 – 195.6	597.65	4.220	23.52
Polythene & plastic	18.24	2.38	0 – 143.8	803.18	2.715	7.671
Food /kitchen waste	192.18	25.63	0 - 2157	94588.9	3.965	19.46
Glass & ceramic	1.53	0.88	0 – 101.3	110.83	8.360	72.03
Cardboard	4.05	1.50	0 – 147.6	325.75	6.218	42.22
Others	10.56	3.96	0 – 390.0	2242.83	6.463	43.56

Table 4 - Household waster composition in different socio-economic groups in the city

Socio-economic groups	Paper waste (%)	Polythene & plastic (%)	Food/kitchen waste (%)	Glass & ceramics (%)	Cardboard (%)	Others (%)
High-income	5.17	7.13	80.7	0.1	1.38	5.47
Middle-income	7.97	8.69	74.5	0.89	2.22	5.68
Lower- income	3.96	7.66	83.54	1.03	1.42	2.36

Table 5 – Waste generation rate in different family size of households for the city

Persons/ household	Range		Mean	SD	Variance	95% confidence interval for mean	
	Min	Max				Lower bound	Upper bound
2	33.90	339.50	129.1571	118.75	14102.5	19.32	238.98
4	25.50	532.40	136.97	118.00	13924.57	93.68	180.25
5	30.00	1993.00	240.74	381.67	145676.6	98.22	383.26
6	60.40	1014.60	342.93	314.49	98908.7	195.74	490.11
7	118.80	346.60	236.133	114.055	13008.57	-47.19	519.46
8	179.50	1340.40	680.825	564.189	318309.7	-216.92	1578.5

Highlights

- The household waste (HW) composition showed the great variations among different socio-economic groups of the society.
- The food/kitchen waste constitutes about 75 – 80% part of HW
- Composition of HW suggests its possible utility in compost and biomass energy production.