# Studying Municipal Solid Waste generation and Composition in the Urban areas of Bhutan

**Sherub Phuntsho[1*], Sunil Herat[2**], Hokyong Shon[3], Saravanamuthu Vigneswaran[3],**

**Ichharam Dulal[1], Dechen Yangden[1], Ugyen M Tenzin[1]**

[1]The Department of Urban Development & Engineering Services, Ministry of Works & Human Settlements, Thimphu, Bhutan,

[1]*Tele-fax: +975 2 324338; E-mail: sherub_p@yahoo.com

[2**]Senior Lecturer, Griffith School of Engineering, Nathan Campus, Griffith University, Queensland 4111, Australia.

Tel: +61 7 3735 6682; Fax: +61 7 37357459; E-mail: s.herat@griffith.edu.au

[3]Department of Engineering, University of Technology Sydney, NSW 2007, Australia.

Tel: +61 2 9514 2629; Fax: +61 2 9514 2633; E-mail: hkshon@eng.uts.edu.au

** Corresponding author

**Abstract**

Bhutan lacks the solid waste data which are essential parameters for planning and scheduling of municipal solid waste management (MSWM) systems. The first ever large scale research survey on solid waste generation and characterization in the urban areas of Bhutan was conducted between Nov 2007 and Jan 2008 using the method of waste sampling at source. The MSW generation rates in the urban centres were 0.53 kg per capita per day which consists predominantly of organic wastes of up to 58% indicating great opportunity for composting. Domestic wastes from the households contributed the maximum (47%) component of the total MSW generated from the urban centres followed by wastes from the commercial establishments. Attempt to study the correlation between household monthly income and the waste per capita generation rates did not yield any conclusive result.

***Keywords:*** Bhutan; Municipal solid wastes; household wastes; urban centres; waste characterization

## Introduction

Bhutan is a small landlocked country located in the eastern Himalaya between Tibet-China (in the North) and India (in the east, south and west). Its total population in 2005 was 672,425 (PHCB, 2006) and it has a total area of 38,394 $km^2$ (MoA 2004). Like any other developing country, Bhutan too is facing the challenges of rapid urbanisation with more than 30% of the country's population living in the urban areas which is expected to increase in the next few decades. Although the national annual population growth rate in Bhutan is 1.28% (MoWHS 2007, PHCB, 2006), its average urban population growth rate has been reported to be 7.3% annually with the western region, including Thimphu, experiencing maximum growth rate of about 11% (MoWHS 2007). Thimphu is the capital city of Bhutan with a total population of 79,185 (PHCB, 2006) in 2005 which is more than 40% of the entire urban population in Bhutan.

Bhutan has achieved considerable economic growth although its planned economic development began in only 1961; however, inadequate management of solid waste and wastewater are a conspicuous environmental problem arising due to insufficient infrastructure planning, municipal facilities and services (RSPN 2006). Garbage has become an emerging issue and the problem is particularly noticeable in the largest cities of Thimphu and Phuntsholing (UNEP 2001).

The answer to starting a successful municipal solid waste management system not only depends on the availability of adequate funds but also on proper planning and design of the system using accurate planning tools and reliable data. For developed countries, as solid waste has been a concern for some years, existing data from long-term characterization studies and monitoring of solid waste streams - both on the local and national level - are usually readily available. However such data are usually non-existent in many developing

countries (Hristovski et al. 2007). The data on solid waste generation and composition are the key parameters for planning, designing and implementation of municipal solid waste management systems.

Recognizing the need to have a more reliable solid waste generation and composition data, a survey covering 10 selected towns was conducted between Nov 17, 2007 and Jan 17, 2008 by the Department of Urban Development and Engineering Services (DUDES) under the Ministry of Works and Human Settlement (MoWHS), Royal Government of Bhutan (RGOB). This research study was funded by Danish International Development Agency (DANIDA) under the Environment and Urban Sector Programme Support. The main objective of this research survey was to study the waste generation rates from different sources and their compositions.

The aim of this paper is to report and analyse the data obtained from the above survey. The information presented in this paper would serve as valuable indicator data for the waste managers who so far have been relying on certain assumptions.

## Research Methodology

### Overview of the study area

The study covered 10 towns of Thimphu, Phuntsholing, Samtse, Paro, Gelephu, Damphu, Samdrup Jongkhar, Bumthang, Trashigang and Mongger (Figure 1). There were no specific criteria on the selection of towns, however, these were the towns where the issues of waste management mostly surfaced and incidentally the towns had the most population concentration. The study area has a combined total projected population 160,000 in 2007 which represents 71.2% of the entire urban population of Bhutan projected at 225,000 in 2007 (Table 1).

*Figure 1 here*

*Table 1 here*

**Sampling methods**

The survey targeted a minimum coverage of 30% of the total households, 50% of the total commercial establishments and 50% of the total offices within the survey towns for waste sampling and interviews. Each town was divided into several survey zones using the latest available maps from DUDES. In the absence of disaggregated population data in each zone, the number of buildings shown on the maps and development control rules regarding maximum number of floors were used to calculate the approximate number of household in each survey zone. The percentage of the total households in the survey zone was calculated by determining the approximate settlement density through satellite maps and then accordingly assigning a percentage of the total households in each of the zone. Having decided the target sample size for each survey town, the sample size of each survey zone was calculated based on the percentage of the total households in the zone. Survey enumerators visited a fixed number of 20 households every day and distributed waste sampling bags. The households were randomly selected within the survey zone and were provided with one or two standard waste sampling bags, which consisted of black biodegradable plastic bag of size 40cm x 65cm x 2.5cm. The same procedure was followed for waste sampling from the commercial establishments and offices however using larger sampling bags of 50 litres made of polypropylene.

**Sample collection, sorting, measurement and recording**

The waste samples were then collected from the household the next day and then transported to the designated municipal disposal sites or landfill sites. The contents were then weighed to

determine its loose waste bulk density. The samples were then spread flat on HDPE sheet on the ground and manually sorted into eight different components: paper/paperboards, plastics, organics, textiles/leather, metals, electrical/electronics, glass and others. Each component was weighed and recorded and the total weight of all the components checked against the original weight of the samples.

## Results and Discussion

### Demographic and socio-economic characteristics of the sample population

The actual survey covered 11068 households, which account for a total sample population of 52371. The sample coverage is therefore 32.8% of population in the survey towns and 23.3% of the entire urban population. The average household size of the sample population was 4.7 persons which was quite close to the national average of 4.6 (PHCB 2006, NSB 2007) and the sample population included all formal and non-formal residences in the town without distinction. Many socio-economic and other variables influence the rate of solid waste generation rates (Kockett et al. 1995), however, in this study we have assumed that all sections of different income group have been covered during the random sampling.

### Municipal solid waste generation & compositions

### Sources and types of waste included in this survey

When reporting the quantity generation and composition of municipal solid waste, it is also important to clearly specify the types of wastes included and excluded in the survey. In this particular study not all the non-household sources could be included because of the difficulty in sampling and due to logistical reasons. The non-household waste sources excluded in the sampling are: institutions (schools, institutes, hospitals) and weekly markets.

**Household waste**

***Mean household waste per household:*** It was observed that each household with an average of 4.7 persons (HH size) generates domestic waste ranging from 0.6 to 1.2 kg per day (Table 2). The mean household waste generation rate in the 10 survey towns was 0.96 kg per household per day.

***Mean household waste per capita:*** The average per capita household waste generation was observed between 0.18 kg per day and 0.36 kg per day with the mean of 0.25 kg per day (Table 2).

*Table 2 here*

**Non-household wastes**

**Commercial sources:** A total of 2311 waste samples were collected from the commercial establishments including retail shops, restaurants & bars, general shops, groceries (Table 3). It was observed that each commercial establishment produces waste ranging from 1.6 kg per day to 3.1 kg per day with a mean of 2.4 kg per day. Bumthang showed the highest mean of 3.12 kg per day followed by Paro 3.1 kg per day. These two towns together with Thimphu host the maximum number of hotels and resorts suggesting that the hotels contribute large quantities of wastes compared to other commercial sources.

*Table 3 here*

**Office sources:** The response to waste sampling from the offices was rather poor and only a total of 351 waste samples from office sources were collected from the 10 survey towns (See Table 4). Most offices in Thimphu did not return the samples during the collection schedule. The sample offices had an average staff of 16.5 which produced non-household waste

ranging between 1.0 kg and 2.9 kg per day with a mean of 1.57 kg per day. The mean non-household waste generated per employee was 0.21 kg per day.

*Table 4 here*

**Composition of MSW**

A total of about 30 tons of municipal solid waste were segregated into eight different components. The results of the waste analysis in the 10 survey towns are shown in Table 5. To supplement the composition data, mixed municipal solid waste were also sampled from few randomly selected municipal collection trucks at Thimphu and Phuntsholing. The results of this analysis are combined to determine the average composition fraction for the 10 survey towns.

**Organic** (50%-66%): The organic waste constituted on average the highest (58%) fraction of the total municipal solid waste generated from the urban areas. Organic waste is mainly composed of kitchen wastes such as vegetables, fruits, food remains, etc and not much garden wastes were observed. The highest organic fraction found in Samdrup Jongkhar and Phuntsholing could be due to food items being cheaper in the south combined with the hot climatic conditions spoiling food faster, thus generating more waste. Organic waste formed the highest fraction for all the wastes sources and household wastes formed maximum organic fraction at 62%. The average organic fraction of MSW would be higher if waste generated from the weekly markets were included. From visual observation weekly market wastes in Thimphu contain as much as 70 to 90% organic content.

**Paper & paperboard:** (11%-25%): Paper and paperboard formed the second highest (17%) fraction of the municipal solid waste. This category of waste included all paper products (printed or plain paper, newspapers and magazines, notebooks), all types of corrugated and

non-corrugated carton boxes and packages, etc. Carton boxes were sourced mainly from commercial establishments, although offices and household also produced significant quantities. Most carton boxes observed in the waste were damaged however, few were intact or reusable. As expected, offices generated the highest paper and paperboard fraction (31%) followed by commercial sources (21%).

**Plastics** (9%-16%)**:** Although the uses of plastics for carry bags, package wrappers and pouches have been banned in Bhutan since 1999 through a government decree, plastic waste formed up to 13% of the total municipal solid waste generated in the urban areas. Plastic waste is composed mainly of packaging, plastic products, hard and flexible plastic household items, PET bottles, Jerry can, etc. Plastic waste especially packaging materials does not decompose and compact easily which is why it significantly affects transportation cost and landfill life.

**Textiles/leathers** (3%-11%)**:** The textiles and leather component formed the third highest fraction (4.7%) of the municipal wastes. Textiles included both organic based (such as cotton, jute, etc.) and synthetic based (synthetic clothes, wrappers, bags). The leather component mainly consisted of leather shoes, bags, belts, and other leather items. Most of the textile and leather waste observed was that which was completely worn out indicating that useable clothes and shoes are seldom thrown out as waste.

**Glass** (2%-9%)**:** Glass on average made up only 3.7% of the municipal sold wastes. Glass mainly consisted of beer bottles, liquor bottles, and other beverage and juice bottles. While intact glass bottles were also observed, most of the glasses was either broken bottles or household utensils. Although the residents were asked not to withhold any recyclable wastes at home during the survey period, few intact bottles were observed in the samples indicating

that recyclables were in fact removed from the sample waste stream. This could be one reason why the glass and the metal component have remained low in our observations.

**Metals** (0-3%)**:** The composition of metals was a mere 0.7% indicating that metal scrap are normally not disposed off as municipal waste. Most residents prefer storing metal scraps at home for later sale to scrap dealers. With metal, especially steel prices ever rising, the metal scraps can have high resale values. Some municipalities in the south have complained about the frequent theft cases of municipal property such as manhole covers, MS fencing, boundary poles, electric transmission poles, etc; which are smuggled across the border for sale as scrap.

**Electrical and electronics** (0-2%))**:** Electrical and electronic wastes formed only 0.4% of the total municipal wastes and it consisted mostly of printer cartridges from the offices. It should be mentioned here that most electrical and electronic equipments such as TV, computers, rice cookers, etc became popular only recently. Electronic gadgets and other equipment are still limited in Bhutan and hence are expected to be used for its full life, repaired if possible unlike in developed countries where electronic and electrical equipments are readily available often discarded due to changing fashion.

**Others** (0-5%)**:** Those few categories of waste such as ash, dust, ceramics, construction wastes such as timber, sand and gravels, household potential hazardous wastes such as dry batteries, household chemicals, or any other wastes that cannot be distinctly classified under any of the above seven categories were all classified as Others. This fraction formed 2.6% of the total municipal solid wastes only.

*Table 5 here*

**Total household and non-household waste generation in urban centres**

The total actual MSW generated from the entire urban areas of Bhutan includes household wastes and non-household wastes from all sources (commercial, offices, institutions and weekly vegetable markets). The results from survey have been used for determining the total MSW generated from the entire urban areas. Since generation rates from sources such as institutions and weekly market could not be assessed through this survey, the most recent figures reported in the existing literature have also been used to estimate the total MSW generation from the entire urban areas.

Table 6 shows that about 43700 tonnes of municipal solid wastes was estimated to have generated from the urban centres of Bhutan in 2007 in which the domestic or household waste formed the highest component (47%). Non-household waste from the commercial sources made up the next largest component of the municipal solid wastes at 23%. Non-household waste from offices made up 12%, schools and institutions 8.0% and weekly vegetable markets 10%. The average per capita municipal solid waste generation has been therefore estimated at 195 kg per year or 0.53 kg per day in the urban areas of Bhutan.

*Table 6 here*

**Density of municipal solid wastes**

Waste density is a very important parameter for planning, scheduling and designing of MSWM infrastructure. The average loose or bulk density of the municipal solid wastes from all three sources was observed to be about 160 kg per cubic meter. The density of the wastes once in the compactor truck could be as high as 300 to 400 kg per cubic meter indicating that the compactor truck of equal volume capacity can carry more than double the quantity of waste that non-compacting trucks can carry. The low density is therefore an indication that

open non-compacting trucks are not suitable for the collection of municipal solid waste. It also indicates that if the waste is simply in the landfills without compaction, the life of the landfills would be significantly reduced.

**Household income as a factor for waste generation rates**

1149 household waste samples were randomly selected to observe the correlation between household income group and the waste generation rates. There is currently no national standard on the definition of different income group and without such standard this grouping was devised solely for the purpose of this study. Figure 2 shows a positive correlation between the income and the waste generation rate up between income groups A to D after which the correlation was observed poor.

*Figure 2 here*

**Conclusion**

The average household waste generation in the urban centres is 0.96 kg per HH per day while the per capita household waste generation is 0.25 kg per day. Average non-household waste generation rates are 2.36 kg per day per commercial establishment, 1.44 kg per day per office or 0.33 kg per employee per day. The total MSW generated from the urban areas of Bhutan in 2007 has been estimated at 43700 tons per year with an average per capita generation 0.53 kg/day. This compares well with per capita generation of 0.62 kg/day in Mostahanem City, Western Algeria (Guermoud et al., 2009), 0.676 kg/day in Chihuahua, Mecxico (Gomez et al., 2008), 0.4 kg/day in Kharagpur, India (Kumar and Goel, 2009) and 0.39 kg/day in Allahabad, India (Sharholy et al., 2007).

Household waste formed the major portion (40%) of the MSW followed by commercial sources at 35% of the total surveyed. In the MSW composition study, organic waste formed

the largest fraction of the MSW with 58%, followed by paper/paperboards (17%), plastics (13%), textiles/leather (4.7%), glass (3.7%), metals (0.7%), electrical/electronics (0.4%) and others 2.6%. High organic content of the urban MSW indicates an opportunity to give top priority to the recycling of organic wastes through composting. The authors would like to reiterate that the above data must be developed and updated continuously through long-term study which will take into consideration many factors medium and long-term trends.

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Table 1: Population details of the 10 survey towns

| Towns | Total population (2005) | Average Population growth rate (%) | Population 2007 (projected) |
|---|---|---|---|
| Thimphu | 79,185 | 11.1% | 97,740 |
| Phuntsholing | 20,537 | 11.1% | 25,349 |
| Samtse | 4,981 | 11.1% | 6,148 |
| Paro | 2,362 | 11.1% | 2,915 |
| Gelephu | 9,199 | 5.0% | 10,142 |
| Damphu | 1,666 | 5.0% | 1,837 |
| Samdrup Jongkhar | 5,952 | 1.4% | 6,120 |
| Bumthang | 3,246 | 5.0% | 3,579 |
| Trashigang | 2,383 | 1.4% | 2,450 |
| Monggar | 3,502 | 1.4% | 3,601 |
| Total for 10 towns | 133,000 | | 160,000 |
| Total for all urban centres in Bhutan | 196,000 | 7.3% | 225,000 |

Sources: Base year population for 2005 (PHCB, 2006) and growth rate (MoWHS 2006)

Table 2: Average household waste generation rates in the 10 survey towns

| Name of the Towns | Total samples | HH size (P/HH) | (kg/HH/day) | | (kg/capita/day) | |
|---|---|---|---|---|---|---|
| | | | Mean | Median | Mean | Median |
| Thimphu | 1762 | 5.1 | 0.97 | 0.73 | 0.22 | 0.15 |
| Phuntsholing | 1707 | 4.6 | 1.20 | 0.96 | 0.34 | 0.22 |
| Samtse | 797 | 4.3 | 0.74 | 0.59 | 0.19 | 0.14 |
| Paro | 851 | 4.5 | 1.23 | 0.96 | 0.36 | 0.22 |
| Gelephu | 1805 | 4.8 | 0.92 | 0.67 | 0.23 | 0.15 |
| Damphu | 819 | 4.8 | 0.77 | 0.54 | 0.18 | 0.12 |
| Samdrup Jongkhar | 1128 | 4.7 | 0.88 | 0.68 | 0.21 | 0.15 |
| Bumthang | 717 | 4.9 | 1.02 | 0.75 | 0.28 | 0.17 |
| Trashigang | 837 | 4.5 | 0.66 | 0.47 | 0.18 | 0.10 |
| Monggar | 645 | 4.4 | 0.95 | 0.70 | 0.28 | 0.17 |
| Average for 10 towns | 11068 (total) | 4.7 | 0.96 | 0.70 | 0.25 | 0.16 |

HH: Household, P: Persons

Table 3: Average waste generation rates from commercial sources

| Name of the Towns | Total sample | (kg/commercial unit/day) | |
|---|---|---|---|
| | | Mean | Median |
| Thimphu | 175 | 2.74 | 1.72 |
| Phuntsholing | 488 | 1.66 | 1.08 |
| Samtse | 134 | 2.75 | 1.44 |
| Paro | 201 | 3.10 | 2.62 |
| Gelephu | 293 | 1.64 | 0.81 |
| Damphu | 108 | 2.84 | 2.26 |
| Samdrup Jongkhar | 294 | 1.89 | 0.97 |
| Bumthang | 234 | 3.12 | 2.34 |
| Trashigang | 162 | 2.85 | 1.88 |
| Monggar | 222 | 2.85 | 2.35 |
| Average for all towns | 2311 (Total) | 2.40 | 1.53 |

Table 4: Mean non-household waste generation rates from office sources

| Name of the Towns | Total office samples | Mean staff/office | (kg/office/day) | | (kg/staff/day) | |
|---|---|---|---|---|---|---|
| | | | Mean | Median | Mean | Median |
| Thimphu | 22 | 19.2 | 2.95 | 2.43 | 0.22 | 0.11 |
| Phuntsholing | 115 | 14.9 | 1.43 | 0.70 | 0.21 | 0.07 |
| Samtse | 49 | 17.9 | 1.10 | 0.71 | 0.17 | 0.05 |
| Gelephu | 38 | 20.1 | 1.65 | 0.63 | 0.15 | 0.04 |
| Damphu | 14 | 10.7 | 1.02 | 1.06 | 0.21 | 0.08 |
| Samdrup Jongkhar | 57 | 18.5 | 1.73 | 0.48 | 0.19 | 0.07 |
| Trashigang | 47 | 18.6 | 1.36 | 1.01 | 0.28 | 0.06 |
| Monggar | 9 | 7.9 | 1.59 | 1.18 | 0.37 | 0.18 |
| Average for all | 351 (Total) | 16.5 | 1.44 | 0.82 | 0.21 | 0.08 |

Table 5: Composition of municipal wastes for the 10 survey towns

| Towns | Papers and paper boards | Plastics | Organics | Metals | Glasses | Textiles/ leathers | EL&ET | Others |
|---|---|---|---|---|---|---|---|---|
| Thimphu | 24.6% | 13.5% | 50.5% | 0.5% | 3.7% | 3.1% | 0.2% | 4.0% |
| Phuntsholing | 14.1% | 12.1% | 65.4% | 0.4% | 2.3% | 3.5% | 0.2% | 2.1% |
| Samtse | 11.9% | 12.5% | 65.8% | 0.7% | 2.9% | 4.6% | 0.6% | 1.0% |
| Paro | 14.3% | 15.0% | 58.3% | 0.7% | 4.7% | 5.8% | 0.0% | 1.3% |
| Gelephu | 15.2% | 13.9% | 56.1% | 0.6% | 3.1% | 6.9% | 1.1% | 3.2% |
| Damphu | 20.0% | 16.3% | 51.6% | 1.8% | 3.0% | 5.9% | 1.4% | 0.0% |
| S-Jongkhar | 16.5% | 10.7% | 60.8% | 0.3% | 2.5% | 3.4% | 0.3% | 5.4% |
| Bumthang | 10.9% | 13.0% | 52.4% | 3.0% | 8.7% | 11.4% | 0.0% | 0.6% |
| Trashigang | 17.8% | 9.8% | 59.0% | 0.7% | 3.8% | 4.8% | 0.6% | 3.4% |
| Monggar | 14.3% | 9.3% | 62.8% | 0.0% | 6.5% | 6.4% | 0.7% | 0.0% |
| **Average** | **17.2%** | **12.7%** | **58.0%** | **0.7%** | **3.7%** | **4.7%** | **0.4%** | **2.6%** |
| Residential | 15.2% | 13.1% | 62.2% | 0.7% | 2.7% | 4.2% | 0.1% | 1.8% |
| Commercial | 21.4% | 10.8% | 50.8% | 0.7% | 5.9% | 6.2% | 0.7% | 3.4% |
| Offices | 31.3% | 16.0% | 35.3% | 0.4% | 2.6% | 3.2% | 1.9% | 9.4% |
| Municipal bins | 14.8% | 14.4% | 58.7% | 0.6% | 4.0% | 4.4% | 0.4% | 2.7% |

Table 6: Total municipal solid waste generation in the entire urban centres from various sources

| Types of wastes | Generation rates | Qty. | Total qty. generated (Tons/year) | % distribution from each source |
|---|---|---|---|---|
| Household wastes | 0.25 kg/person/day | 224,527 p | 21,000 | 47% |
| Non-household wastes | | | | |
| Commercial sources | 2.36 kg/unit/day | 20,688 licences [a] | 10,000 | 23% |
| Office sources | 0.21kg/employee/day | 70,132[b] employees | 5,000 | 12% |
| Weekly veg. markets | 0.30[c] kg/person/week | 224,527 p | 3,500 | 8.0% |
| Schools and institutions | 0.10 [d] kg/person/day | 117,734[e] total enrolled | 4,200 | 10% |
| Total estimated in 2007 | | | 43,700 | 100.0% |
| Average per capita total MSW generation | 195 kg/p/year<br>0.53 kg/p/day | | | |

[a] Total licenses issued as of 31-12-2007 ( DoT 2008). [b] Total urban population employed as of 2005 in all the sectors (PHCB 2006). [c] About 10T of MSW generated every week from Thimphu vegetable market equivalent to average 0.3 kg per person per week. [d] Average waste generated from the schools and institutions (Penjor 2007). [e] Total enrolment in 2007 in all schools & institutions including NFEP and day care centres in the urban centres which is 65% of the total 181,129 enrolment.

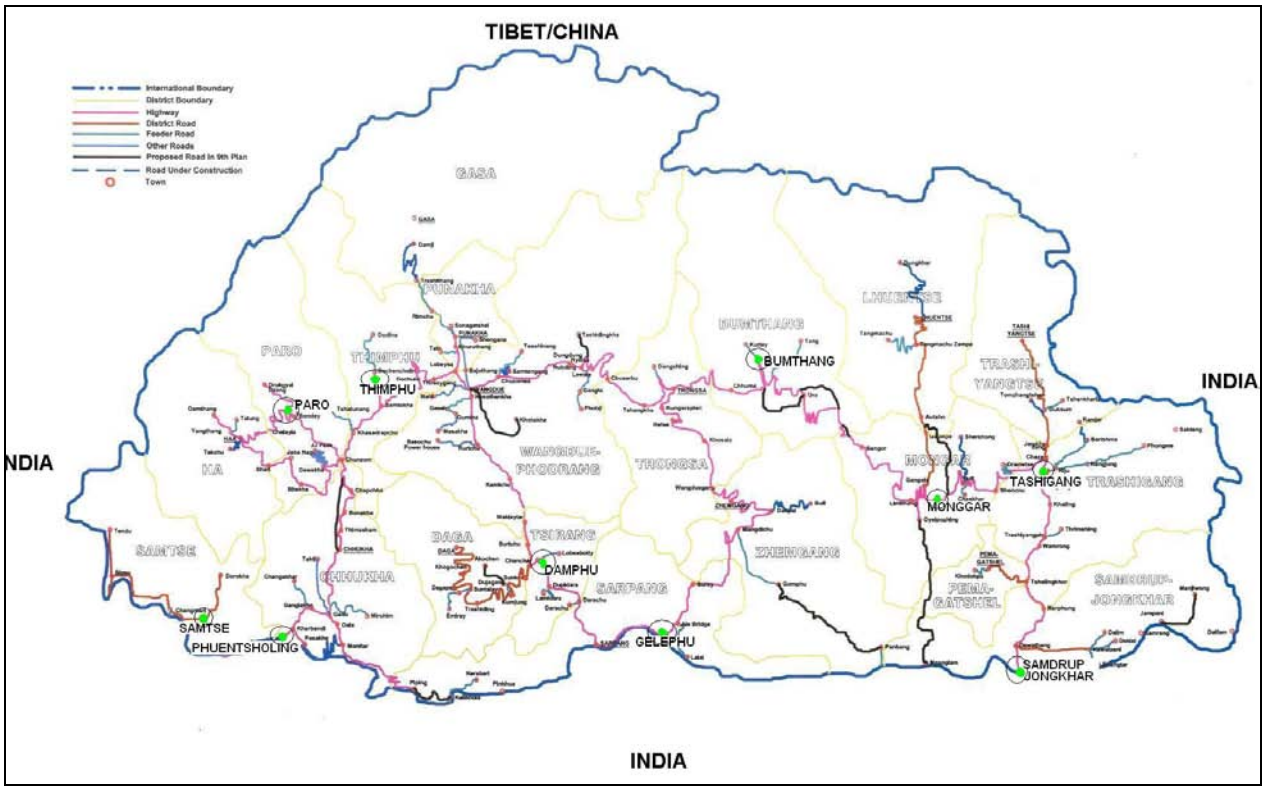


**Figure 1:** Map of Bhutan with 20 districts and the location of the 10 survey towns

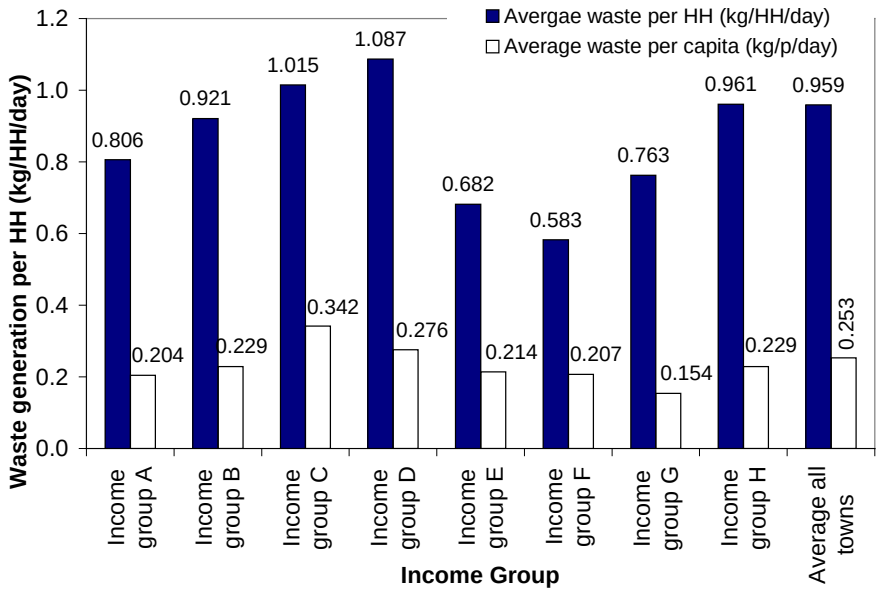


**Figure 2:** Monthly household income group vs. household waste generation rates.

Income group A: <Nu.10,000, B: Nu.10,001-20,000, C: Nu.20,001-30,000, D: Nu.30,001-40,000, E: Nu.40,000-50,000, F: Nu.50,000-75,000, G: Nu.75,001-100,000, H: Nu.100,000+. Currency conversion 1.00 US$ ~Nu 40 at the time of survey.