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Design of Temporary Storage of Municipal Solid Waste and Its Impact on Global Warming –A Case Study

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Abstract

Municipal Solid Waste (MSW) Management continues to remain as one of the most challenging task in urban development. Despite the fact that the core environmental impact is linked to the emissions of landfill gases of MSW, the production of collection bins for Temporary Storage (TS) of MSW, also makes a substantial contribution to environmental impact. This paper presents a methodology to estimate the amount of emissions produced during the production of High Density Poly Ethylene (HDPE) collection bins. The MSW collection bins required is evaluated based on bin size, population, percapita solid waste generation and collection frequency. In this paper, the number and size of MSW collection bins, bin density and catchment area for various collection frequency for Coimbatore city is designed with the environmental impact indicator-Global Warming Potential (GWP) based on the predicted waste generation for a decade (2008-2017). This long term predictions could be useful to waste management organizers to select sound environmental management strategies.

Keywords: Collection bins, Emissions, Environmental impact, Global warming potential, Municipal Solid Waste, Temporary storage

1. Introduction

In many countries, environmental issues on Municipal Solid Waste (MSW) management decisions are prime concern for environmentalists and decision makers in government agencies. Among the driving force of these issues, is threat to global climate change. The climate change is the serious international environmental concern and subject of much research. Many scientists are alarmed by a significant increase in the concentration of Carbon dioxide (CO_2) and other green house gases (GHG) in the atmosphere. Since the pre industrial era, atmospheric concentrations of CO_2 have increased by nearly thirty percent and Methane (CH_4) concentrations have more than doubled (**Mccarthy J.J 2001**). By addressing a broader set of MSW management options, a more comprehensive picture of GHG emissions in the waste sector is determined and the relative GHG in waste management could be assessed. One way of reducing emissions of GHG, from the MSW management is to understand and choose environmentally sound MSW management options.

In India, the production of solid waste per person is 500 g per day in urban areas **(CPCB 2000)**. The solid waste generation varies from town to town depending upon the density of population. The rate of solid waste generation depends on various factors namely population density, existing commercial and industrial activities, life style and climatic conditions etc. The report of high power committee on urban solid waste management in India reported that system of segregation of organic, inorganic and recyclable wastes at household levels is not implemented (**Planning commission, 1998**). Further, the disposal of MSW is by unplanned and uncontrolled open dumping at the landfill sites.

The collection bins act as Temporary Storage (TS) for MSW generated from the household. The stage of TS is the point where waste leaves the house and enters waste management system. The input is based on source sorted waste materials, which have estimated. Output is different waste materials that are stored in bins. It has to be noted that TS as a contact point between waste generators and waste management system should be carefully managed (**Darmstadt et al, 2005**). The waste management systems that fail to receive balance in this relationship are unlikely to succeed.

A limited research work has been reported in literature about the design of TS. Hence, it is planned to take systematic work to estimate the size and number of bins with different collection frequencies. The design of TS should be integrated with other MSW management options to abate degradation in urban environment. The production of galvanized steel MSW collection bins of 1100 litres (L) volume leads to the threefold higher impact on global warming and twenty-three fold higher human toxicity than same size of High Density Poly Ethylene (HDPE)(**McDougall et al, 2001**).Hence collection bins of HDPE material is considered in this study.

The design of TS for MSW can be accomplished through promotion of economically efficient and environmentally sound design options. The short-term predictions on generation of MSW for the design TS can facilitates better understanding with respect to collection, transport and final disposal of MSW. However, long term forecasting could be very useful to waste management organizers to select appropriate design strategies. To assess environmental impact in the design of TS, the impact indicator-Global Warming Potential (GWP) is considered. In this paper, GWP is assessed in the design of TS for a decade (2008-2017) for Coimbatore city, India. The assessment of GWP helps to select the suitable design of TS for MSW by responsible decision makers.

2. Study area characteristics- Coimbatore City

2.1 General

Coimbatore city is situated in south India, has around 11º North latitude, 77º East longitude and 432.0m above mean sea level, while the city is flat, it is surrounded by hilly terrain, since it is situated at the foot of Nilgiri hills. As it is exposed to the palghat gap of Westernghats, it enjoys a salubrious climate throughout the year. The maximum temperature observed in this city is 34º C and minimum temperature is 20ºC. April and May are hottest months in the city. This city has an average rainfall of 60 cm.

2.2 Source wise generation of MSW

The MSW is collected from all the places of city such as domestic, industries, markets, marriage halls, street sweeping, hotels, and restaurants. The Figure 1 shows the quantity of wastes generated from various sources of the city. It is estimated that 564 tons of MSW generated from the above sources in a day in the city. The wastes generated from the residential sources account for more volume of the total wastes.

2.3 Population and rate of waste generation

The city has a population of 10, 93,888 spread over an area of 105 km^2. The quantity of zone wise waste generation of MSW and the corresponding population statistics are given in Table1. (**Commissioner of Municipal Administration, India, 2004**). The per capita solid waste generation by Coimbatore dwellers is 516 g per day.

2.4 Material composition of waste

The wastes disposed by the residents are organic in nature (76.95%) and the initial moisture content of organic waste is high (57%). The construction and demolition wastes are not included in the calculation of waste generation. The default values for material composition of waste fractions of MSW are given in Table 2.

2.5 Municipal administration

The entire Coimbatore city is divided into four zones viz North, South, East and West. Each zone has 18 wards. The respective authorities in the different levels monitor MSW management of primary collection, secondary collection and overall activities.

2.6 Methods of storage

At present Coimbatore Municipal Corporation (CMC) has provided 1000L HDPE containers for temporary storage of MSW, which are at specific locations for the residents to dispose the wastes. The bin has top lids for covering the wastes and bottom wheels for moving the bins. In most of the places of the city, adequate numbers of bins are not placed for the disposal of wastes for the residents. Stationary Container Systems (SCS) are used for the disposal of

wastes. Old types of bins are in concrete and most of the bins are damaged. The wastes are thrown and heaped in streets as dumping points. At present only mixed wastes are collected from the city.

2.7 Primary collection of MSW

Both Corporation vehicles and Private vehicles are employed to collect the wastes from the roadside dumping points and HDPE bins. Thirty to forty percent of the waste is left uncollected in streets and part of the waste is disposed by open burning. This is due to the non-availability of the sufficient transportation of fleet, frequent breakdown of vehicles and absenteeism of the crew. House to house collection of solid waste is not practiced in the city. However, in some areas, the welfare association and societies have arranged for house-to-house collection of solid waste on specified monthly payments. The municipal bodies are still facing increasingly serious problems for the collection of wastes due to generation of the huge quantity of MSW. However, hospitals are expected to manage their own wastes.

2.8 Secondary collection/transportation of MSW

In the city, the western and southern zones of wastes are collected and transferred to the disposal site through the transfer stations at Ukkadam. The eastern and the northern zone MSW is directly hauled by the collection vehicle from the collection point to the disposal site. Table 3 potrays to the total number of owned and hired vehicles used for the purpose of primary collection and secondary collection / transportation of MSW to the dumping yard of city. It is inferred from the Table 4 that more number of diesel vehicles are used for carrying the MSW.

2.9 Present status of disposal of MSW

The wastes are collected through open body trucks and are dumped in the recognized open dumping site at Vellalure i.e. unsanitary landfills. Since the disposal site is within 15 to 20km of the collection points, transfer stations are not in use. Previously there were four various transfer stations at Peelamedu, Ondipudur, Sathy Road and Ukkadam. Now only one transfer station at Ukkadam is in use. The disposal site in Vellalure covers an area about 604 acres. Since the wastes are disposed off as crude open dumping, this attracts flies, birds, insects and dogs for breeding. It also leads to odour menace in the neighborhood areas. Often the wastes are burnt to reduce the volume, leading to fire and smoke hazards, which causes air pollution. The emission load of pollutants due to open burning of MSW for the state of Tamilnadu (Coimbatore) is growing at the rate of 3 tons/year **[Chnahi Sinha, 1997].** At present unauthorized rag pickers are involved in the collection of recyclable fractions from the different parts of the city and in the open dumping yard. There are also problems of soil and ground water contamination due to leaching of particles of solid waste caused by surface water and rainfall.

2.10 Proposed treatment yards

The CMC is planning to involve private entrepreneurs to deal with the problem of solid waste management. In this regard, the corporation is planning to supply biodegradable wastes of 100 tones per day and non-biodegradable wastes of 30 tons per day for the composting plant and recyclable yard respectively to the private entrepreneurs. Hundred acres of land is designed to provide an integrated facility for processing, composting and recycling. Proposed recycling yard is at Ukkadam and composting yard at Vellalure. At present composting plant of 100 tons per day capacity (Expandable) and land filling in the adjoining areas at Vellalure is proposed.The proposal is under progress.

Recycling solid waste is an attractive strategy for governing officials because of its potential to reduce disposal costs, conserve available landfill capacity and contribute to national goals of energy and resource conservation **[David.H.Folz,1991].** Institutional weakness, lack of financial resources, inappropriate technologies, occupational health hazard, lack of community participation, waste pickers and their associated problems and political interference are the constraints for the effective implementation of the solid waste management programme **[Santhose Mandal,1998].**

2.11 Proposed action plan submitted to the Supreme Court

With the view of proper disposal of MSW, the CMC has submitted the following action plan to the Supreme Court.

- Organising awareness programme Segregation, Reduction, Reuse and Recycling of the wastes.
- Arrangements to collect degradable and recyclable wastes separately by placing adequate number of two bins in the city.
- Waste collection in bin should be cleared regularly to the disposal site.
- Wastes are to be transported under covered conditions and should not be scattered and spilled during transportation.
- For the proper disposal of MSW, Composting yard for degradable waste, Land filling arrangements for inert and Recycling yard for recyclable waste are to be provided and maintained properly.

3. Materials and methods

The main objective of this research paper is to design TS and evaluate GHG emissions due to the use of HDPE collection bins in terms of GWP. The direct environmental impacts are due to the emissions of the GHG during bin production. The size and number of collection bins are included in the model developed for predicting the GHG emissions. In the modeling, the production of main material used for bin production is considered and the raw material manufacturing processes are not included. For the recycling process, it was assumed that the used containers can be partly recycled into secondary materials. The recycled material along with virgin material is used for bin production, reduces the lower net material consumptions. The emissions from production of collection bins are classified and characterized using the Life Cycle Analysis (LCA) methodology.

3.1 Design aspects of the model

This design of TS has been carried out using theoretical considerations and equations considering various parameters. Standard modules included in the design of TS of MSW are

- Size of bin
- Collection frequency
- Average filling rate
- Number of bins
- Volume of material needed for bin production
- Bin density and
- Catchment area

In the design of TS, municipalities have different options for the selection of number of bins, bin size and collection frequency. The different sizes of bins are considered for degradable and recyclable wastes which mainly depends on the quantity of waste generated and bulk density of the waste fractions. Generally, not all the bins are fully filled every time. The filling of bins should be over 50% and under 100% to account for seasonal influences. This value is assumed equal for both waste fractions in the city .The average filling rates of both the bins are assumed as 80%.

3.2 Impact Analysis

The emissions accounted in the design of TS are arranged into environmental impact categories such as GWP. GWP is used as characterization factors to assess and aggregate the interventions for the impact category on climate change. GWP is an index for estimating relative global warming contribution due to atmospheric emission of a kg of a particular GHG compared to emission of a kg of Carbon dioxide (CO_2). Within each impact category, each emission is multiplied by an equivalency factor to obtain an impact potential value. In the production of bins GHG such as Carbon dioxide (CO_2) and Methane (CH_4) are two air emissions considered to calculate GWP. The Methane GWP includes an indirect contribution from stratospheric water (H_2O) and Ozone (O_3) production. Life time values for methane are adjustment times, which incorporate the indirect effects of emission of each gas on its lifetime. The impact category, their respective emissions and equivalency impact factor applied in this study are based on the report from inter governmental panel on climate change **(IPCC, 2001).**

4. Results and discussion

In order to plan the most appropriate type of waste management system, it is essential to collect reliable information about quantities of waste produced, types and amount of material to be reused or recycled. Future community trends such as population growth and waste characteristics profile should be evaluated to determine appropriate management technique. The waste prognosis is mainly based on the income level, life style, population growth, life expectancy rate and mortality rate of the people in the city. The generation rates estimated so far in various cities are only approximate and an accurate and scientific method of estimating the same is still a complex task for the researchers. Hence in this paper, the waste is predicted based on the per capita solid waste and population growth of the city. Figures 2 and 3 shows the total quantity of wastes generated by the Coimbatore dwellers for degradable and recyclable wastes respectively upto the year 2020.

4.1 Size, number and collection frequency of collection bins

The standard sizes of available HDPE collection bins 80, 120, 240, 660, 770, 1100 and 2500L are considered for evaluating the design options of TS. Size of the bin depends on the quantity of the waste generation, bulk density of the wastes and collection frequency. The numbers of bins are estimated for various collection frequencies of once in a month (12 trips per year), once in two weeks (26 trips per year), Four trips in a month (48 trips per year), once in a week (52 trips per year)) and twice in a week (104 trips per year) for both the degradable and recyclable wastes. The numbers of needed bins for size of 80L and 2500L for degradable wastes with collection frequency of once in a month

are 15, 39,049 and 49,250 respectively. The number of needed degradable bins for size of 80L and 2500L with collection frequency of twice in a week is 17,7,580 and 5,690 respectively. The number of estimated recyclable bins for size of 80L and 2500L with collection frequency of once in a month is 29,2,420 and 9,440 respectively. The number of needed recyclable bins for size of 80L and 2500L with collection frequency of twice in a week is 34,035 and 1089 respectively. This is for the present year 2008. This dramatic difference in the total number of bins for both waste fractions are due to the increasing the collection frequency of wastes from monthly once to twice in a week. Also larger size of bin demands, lesser number of bins for the collection of wastes. Higher collection frequency increases the total number of bins with the increase in bin size. Figure 4 and 5 gives the relation between the number and size of bins for various collection frequencies for projected years for both waste fractions.

4.2 Bin density for collection bins

The bin density (number of persons per bin) for various sizes and collection frequencies are calculated for both degradable and recyclable waste fractions. Figure 6 and 7 predicts the relation between bin density and size of bin for various collection frequencies for both degradable and recyclable waste fractions respectively. Bin density of degradable bins of 1100L and 2500L with collection frequency of once in two weeks and twice in a week are 32, 73 and 130, 292 respectively. Therefore, bin density increases with collection frequencies and decreases with the size of bin. It indicates that number of persons used per bin is high because of increase in the size of bin. It is known from the figure 6 that the numbers of persons per bin varies from minimum of one person per bin to maximum of three hundred persons per bin.

Bin density of recyclable bins of 1100L and 2500L with collection frequency of once in two weeks and twice in a week are 156, 354 and 625, 1420 respectively. Thus, bin density of recyclable bin is increased to twenty percentage higher compared to the bin density of degradable bin. This is due to lesser generation of the recyclable waste fraction.

4.3 Catchment area for collection bins

The catchment areas in hectare (ha) per bin are calculated for various sizes and collection frequencies for both collection bins. Figure 8 and 9 shows the catchment areas for various collection frequencies for degradable and recyclable waste fractions respectively. As the collection frequency increases, the catchment area also increases with increase in size of bin. This implies that the number of bins per ha is less because of increase in size of bin. Lesser catchment area needs more number of lesser size bins. This facilitates stoppage of the collection vehicle more frequently and leads to more of vehicle pollution. In addition, more number of lesser size bins is not recommended due to non-entry of collection vehicle in narrow streets of the city.

4.4 Analysis of GWP on design of TS for MSW

The design of the TS for CBE is environmentally assessed using the GWP. GWP decreases as the collection frequency increases and size of the bin decreases. This is due to use of lesser number of bins with the increasing collection frequency. Figure 10 and 11 shows the relationship between GWP, number of bins for various sizes for degradable and recyclable waste fractions. The recommended size of bins for the degradable waste is 1100L and 2500L because of the more generation of degradable waste. The collection frequencies recommended for the degradable wastes are either once in a week or twice in a week because it starts decomposes at a shorter interval of time, which leads to severe problems in handling and poses bad odour.

With the recommended sizes of bin and collection frequencies for degradable wastes, the suitable bin size and collection frequency of recyclable wastes are chosen keeping the total number of bins as same for the both waste fractions. Thus, four cases for design of TS are recommended and shown in Table 4. The estimated total numbers of bins are for the present year 2008. Depends on the population density, the total number of same size of bins can be increased in every year The total percentage increase in the number of collection bins for ten year is 13% for all the four cases for both waste fractions. Since the life period of the bin is ten years , the replacement of the bin is not necessary for every year. The collection frequency may be based on the available collection vehicles. As population grows, the corresponding generated wastes will increase which increases collection frequency per year. In all above four cases, total the numbers of bins increased every year are same for both waste fractions. This ensures the bins can be placed adjacent to each other for easy disposal of waste for the dwellers. In addition, it is convenient for the citizens to dispose the wastes separately and facilitates complete collection of wastes by collection vehicles. Lesser collection frequency leads to lesser vehicular pollution during collection of wastes. Number of persons per bin for all the above four cases are 68,163,128 and 292 respectively for both fractions (Figure 12). The recommended catchment area for the selected four cases of design options of TS varies from 5 to 23 ha per bin (Figure 13)

The total GWP is analysed for the above four cases and are shown in Figure 14. In case I, the collection frequencies are once in week for both the waste fractions. The same collection frequency for both wastes ensures that either separate or two compartmental vehicles can be used for the collection of wastes. The total GWP during the production of the bins in Case I, Case II, increases 50 % and 41 % respectively with respect to Case III. In case III ,though the GWP is 0.03%

higher than the case IV, but the collection frequency of degradable waste and recyclable waste are once in a week and once in a month respectively. There is lesser GWP during the production of the bins in Case IV, with the collection of degradable waste is twice in a week and recyclable waste is Four trips in a month . Based on the lesser environment impact of GWP, the total number bins can be recommended. However, the collection frequency also has an impact during collection and transport of MSW. Therefore, it has to be analyzed for overall environment impact. Based on the available number of vehicles in CMC, the design of MSW can be selected.

5. Conclusions

For easy disposal of waste, both the bins are placed at same location. It depends on the types of dwelling or commercial and industrial facilities, available space and assess to the collection vehicles. Here SCS are recommended, i.e. it remains at the point of generation. This also ensures the complete collection of the waste fractions by the vehicles. Bins are recommended to be placed at the corner of the each street, for the easy accessibility of the vehicle. The collection frequency varies every year based on the quantum waste generated in each year. In addition, these are decided by the Municipalities based the available number of vehicles. This study is useful to the decision makers in MSW management to choose sound environmental management system. The community awareness in the segregation of the waste fraction ensures the successful implementation of this system.

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Table 1. Zone wise of Generation of Solid Waste and Population

Sl.No	Zone	Number of Houses	Population	MSW Generated in Tons / Day			
				Degradable	Recyclable	Inert	Total
1	East	63,355	2,87,553	102	7.2	22.4	131.6
2	West	59,838	2,66,717	114.4	7.9	21.4	143.7
3	South	46,509	2,38,571	120.4	8.1	19.1	147.6
4	North	59,007	3,01,047	109.4	7.8	23.9	141.1
TOTAL		2,28,709	10,93,888	446.2	31.0	86.8	564.0

Table 2. Material compositions of waste fractions in household waste

Waste Fraction	Waste Materials	Material Contribution Percentage by weight
Degradable	Organic / Biomass	63.70%
	Woody Biomass	12.0 %
	Paper	1.25 %
Recyclable	Plastic	2.20 %
	Glass	0.25 %
	Metal	0.35 %
	Rubber	1.20 %
	Rags / Textiles	1.00 %
	Leather	0.50 %
	Thermocole	0.05 %
Inert	Stones-	5.50 %
	Sand/earth	12.0 %
	Construction debris	Not considered

Table 3. Vehicles used for Collection and Transportation of MSW

S.No	Type of vehicles	Total number of vehicles
Corporation vehicles		
1	Lorries with tipper	9
2	Lorries with non tipper	3
3	Dumper placers	17
4	Bulk Refuse carrier	2
Private vehicles		
5	Hired private lorries	49

Table 4. Recommended design options of TS for MSW (Year 2008)
(D=Degradable waste, R=Recyclable waste)

Size of the bin in L	**Collection frequency**	**Required Number of bins**
Case I		
1100 (D)	Once in a week	26000
240 (R)	Once in a week	26000
Case II		
2500(D)	Once in a week	11500
2500(R)	Once in a month	11500
Case III		
1,100(D)	Twice in a week	13000
240(R)	Twice in a week	13000
Case VI		
2500(D)	Twice in a week	6000
1100 (R)	Four trips in a month	6000

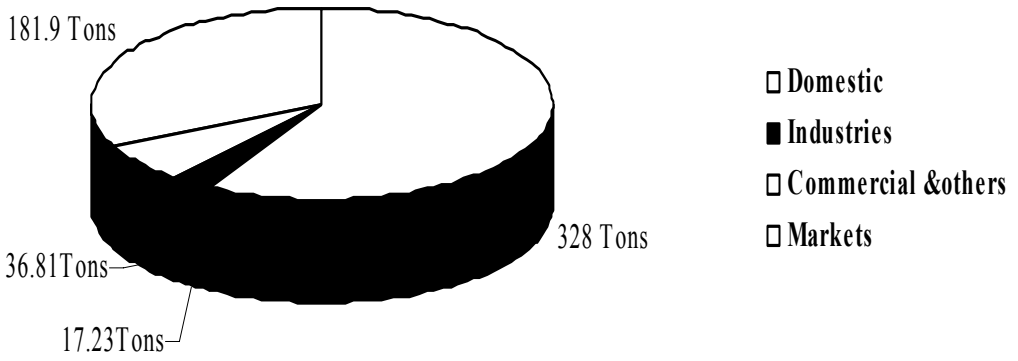

Figure 1. Source wise MSW generation

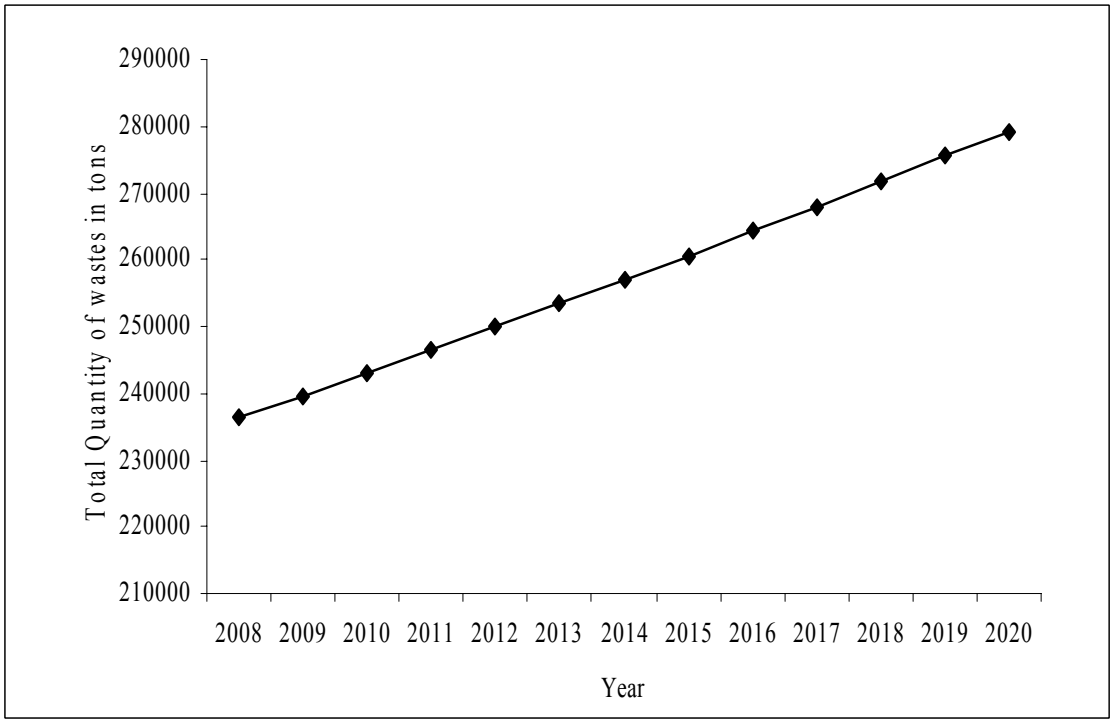

Figure 2. Generation of total quantity of degradable waste

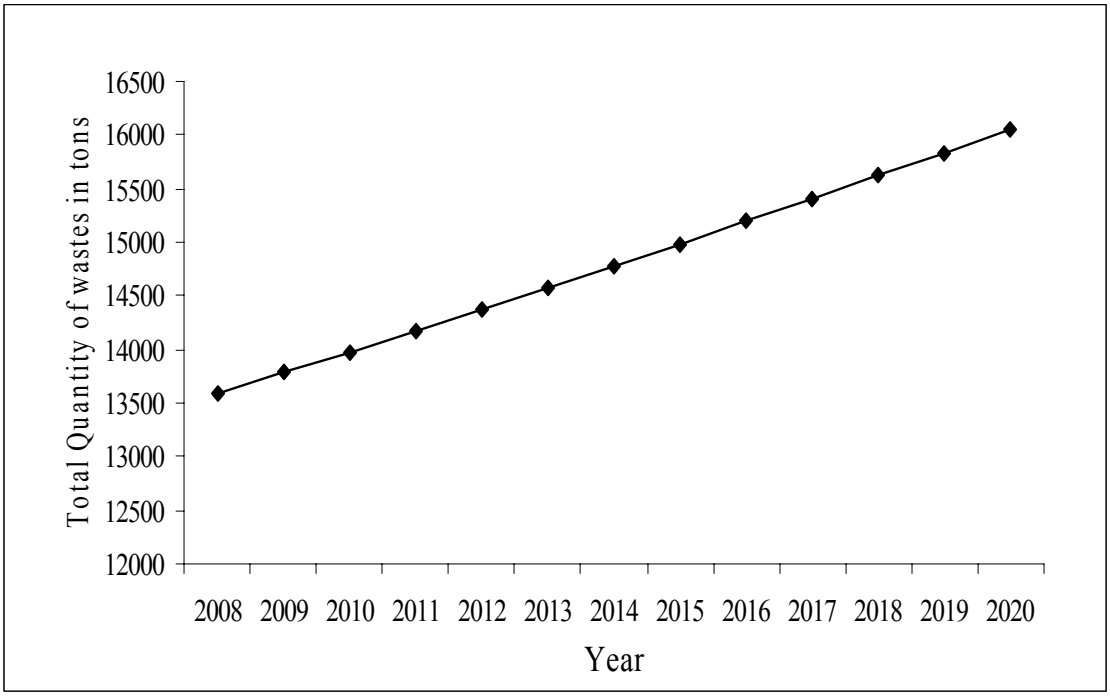

Figure 3. Generation of total quantity of recyclable waste

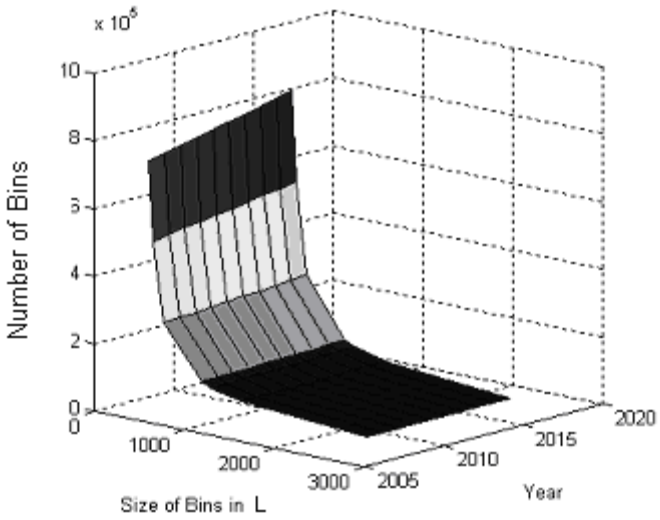

Figure 4. Number and Size of bins for degradable wastes in collection frequency of once in two weeks

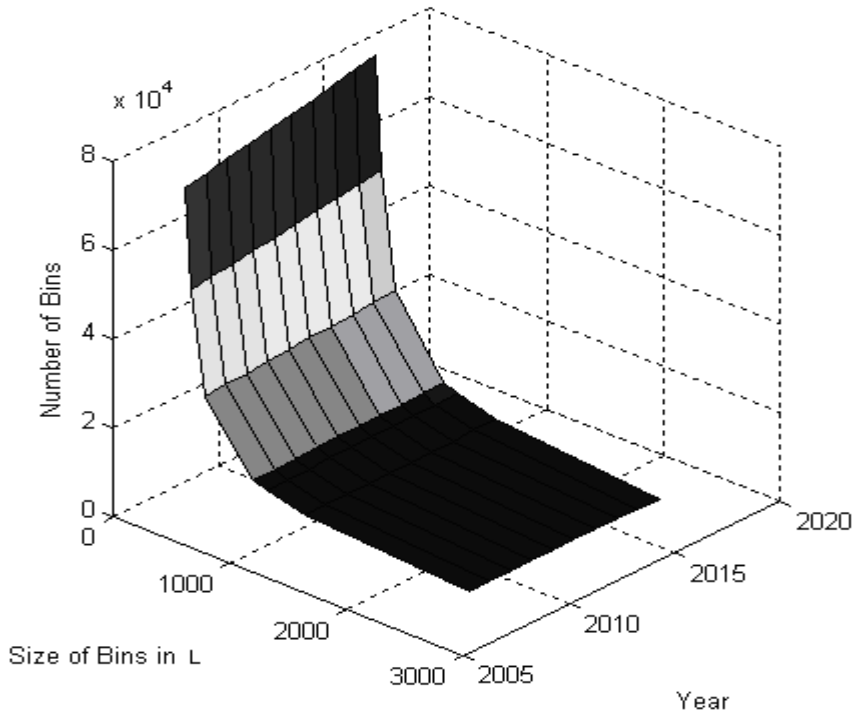

Figure 5. Number and Size of bins for recyclable wastes in collection frequency of once in a week

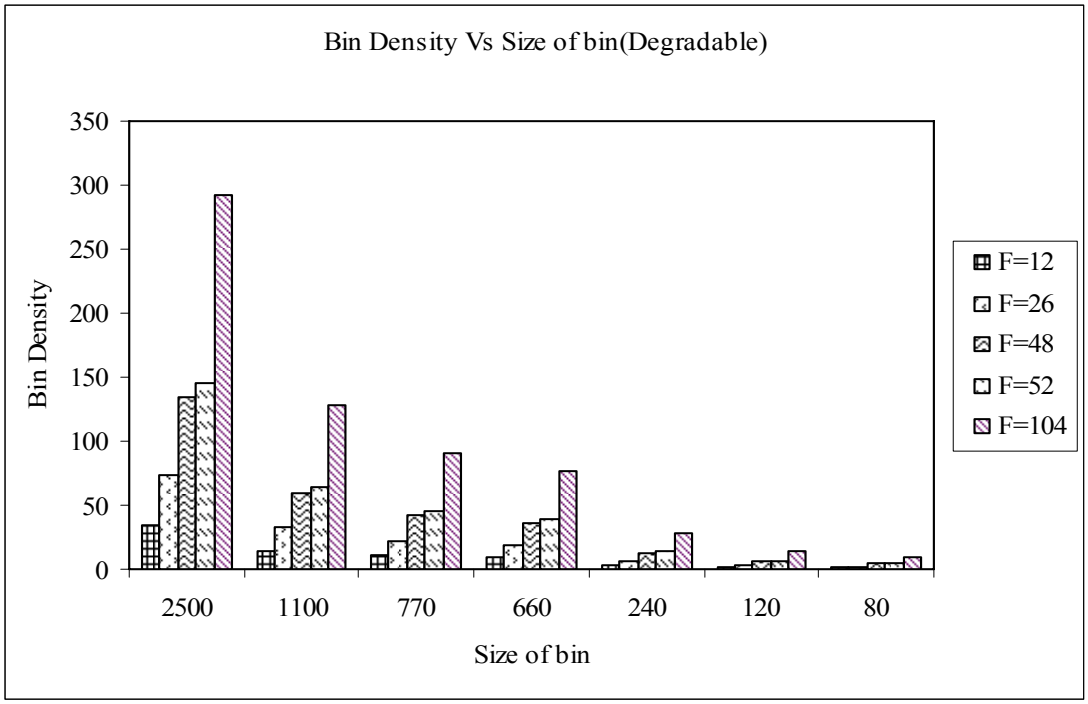

Figure 6. Bin Density and Size of degradable waste bins for various collection frequencies

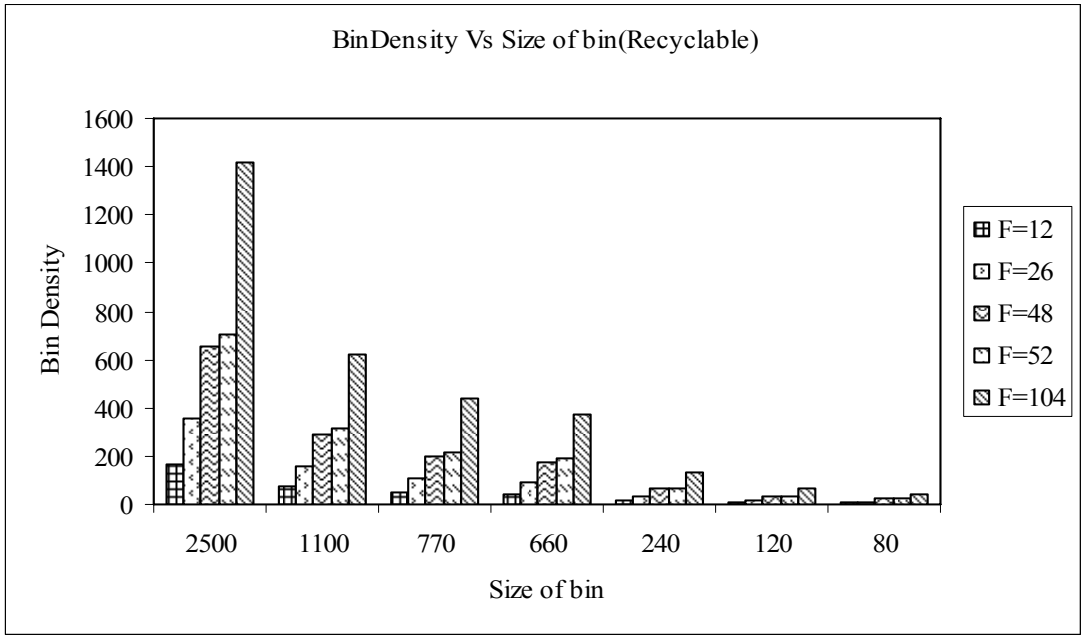

Figure 7. Bin Density and Size of recyclable waste bins for various collection frequencies

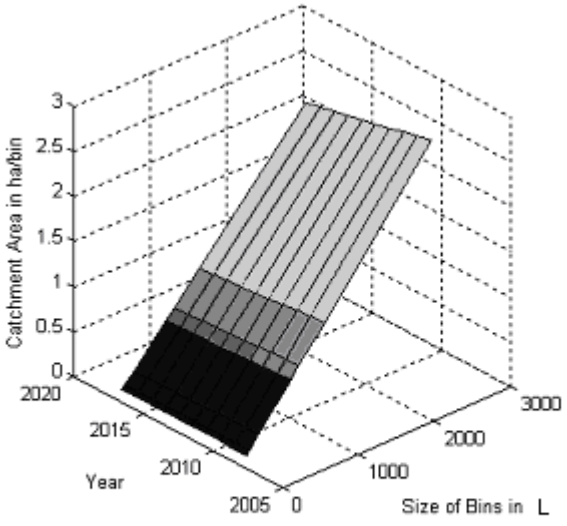

Figure 8. Catchment areas for degradable collection bins at the collection frequency of once in a month

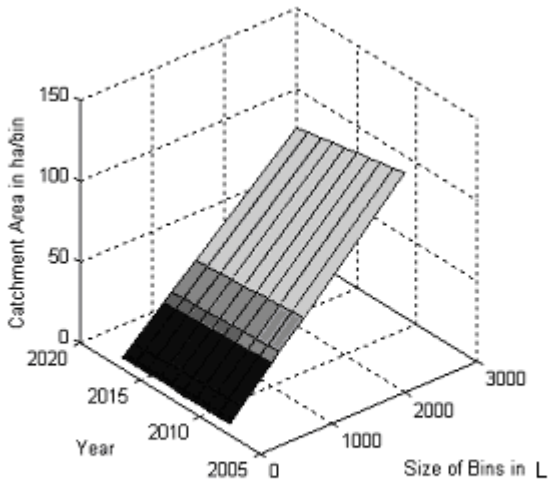

Figure 9. Catchment areas for recyclable collection bins at the collection frequency of twice in a week

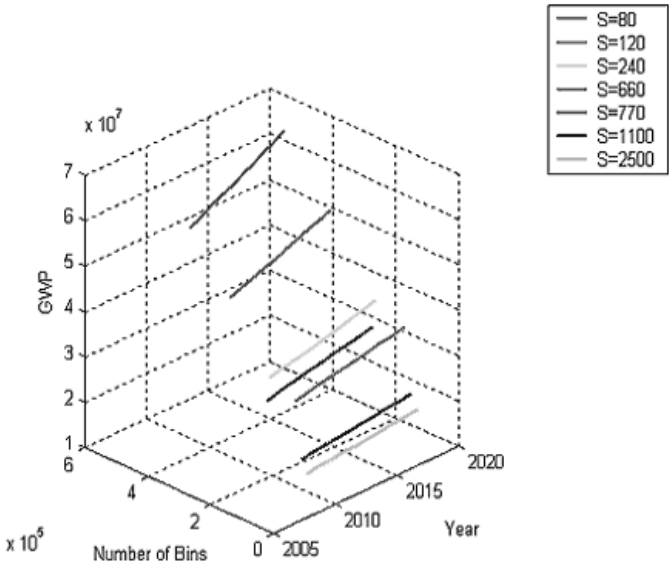

Figure 10. GWP and number of degradable bins for various bin sizes in a collection frequency of four trips in a month

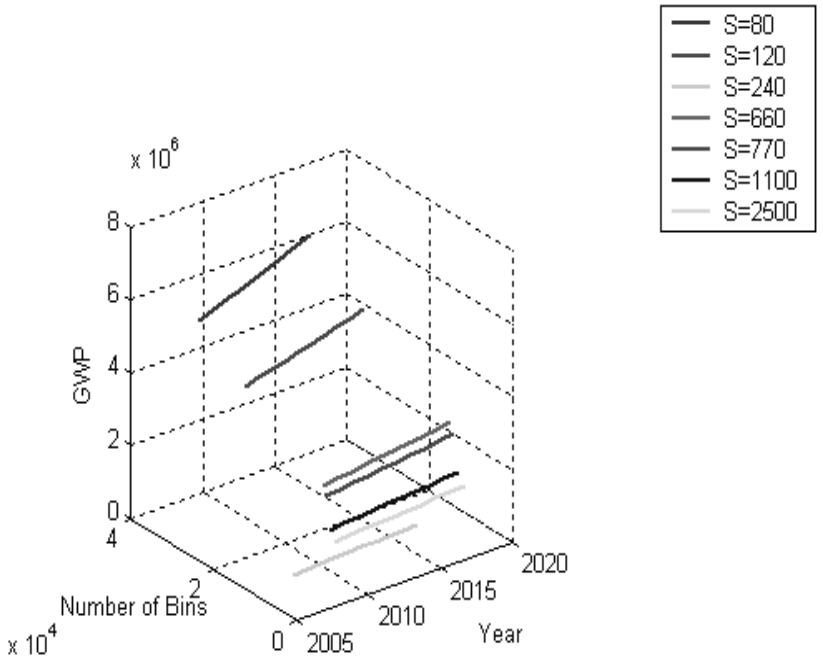

Figure 11. GWP and Number of recyclable bins for various bin sizes in a collection frequency of once in a month

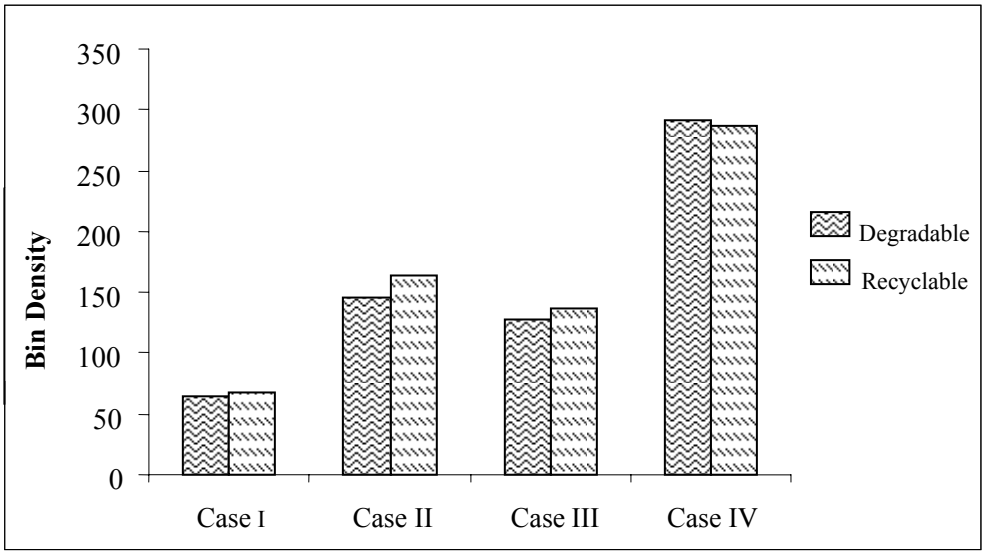

Figure 12. Bin density for recommended options of design of TS

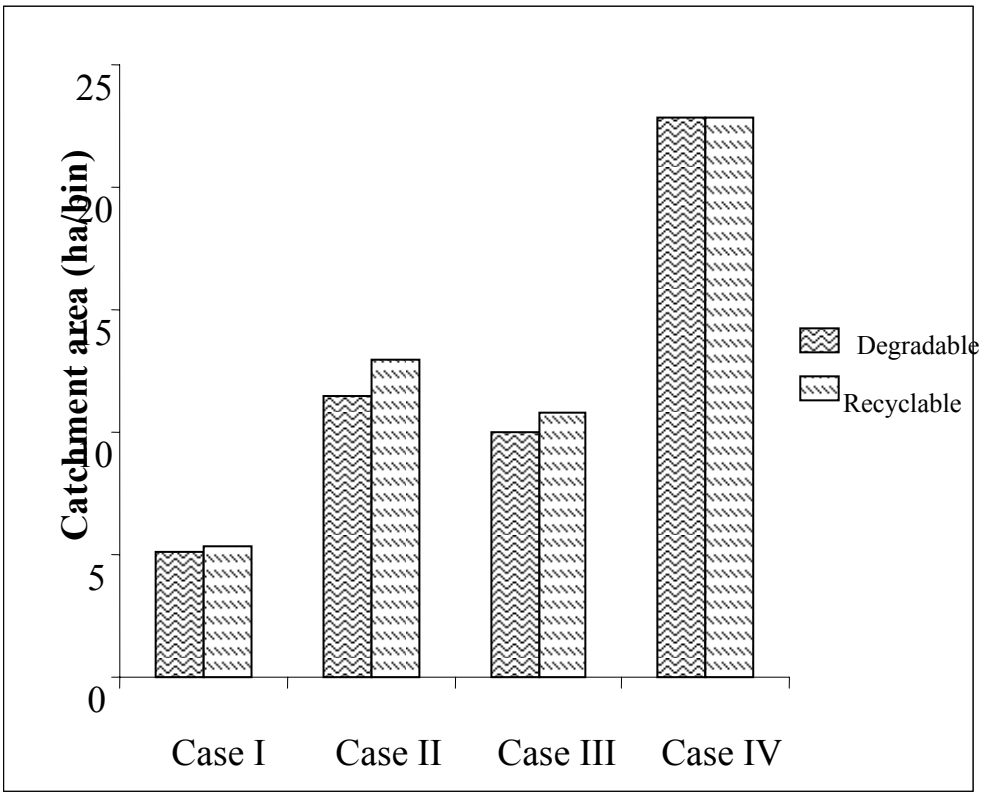

Figure 13. Catchment area for recommended options of design of TS

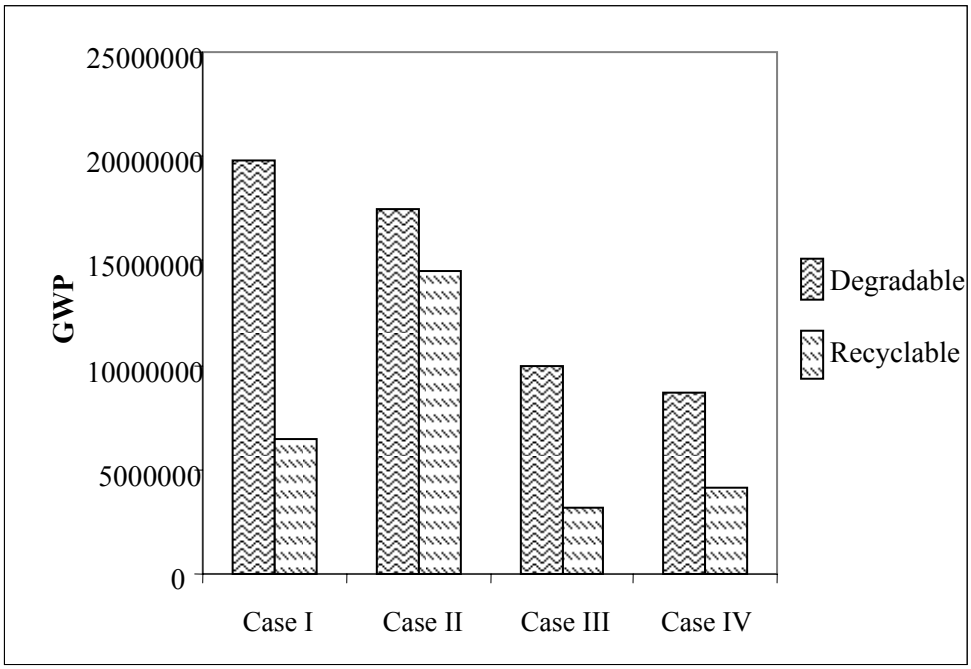

Figure 14. GWP for recommended options of design of TS