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Model Development on Disposal of Municipal Solid Waste through Experimental Studies

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Abstract

The aim of this paper is to assess emissions associated with collection and transportation of Municipal Solid Waste (MSW) for Coimbatore City located in southern India. Despite the fact that the major environmental impact is linked to the emissions of landfill gases, the study shows that vehicles carrying MSW also make a substantial contribution to the impact. A model was developed to predict and quantify the emissions released into the atmosphere. An analysis was carried out to calculate the emissions generated by the diesel vehicles carrying MSW, focussing upon different modes of speed and time interval of collection and transportation in different routes of the city.Two different vehicles were suggested to collect and transport degradable and recyclable waste to the respective treatment yard such as composting and recyclable yard for Coimbatore city. The amount of CO, CO_2, HC, and NO_x emissions generated by the MSW vehicles during the collection and transportation of the degradable and recyclable waste to the proposed treatment yard were quantified. The emissions were predicted by forecasting the generation of MSW based on the population growth up to the year 2020 for Coimbatore city

Keywords: Gas emissions, MSW Collection, MSW Transport, MSW, Environmental impact, Degradable waste, Recyclable waste, Diesel Vehicles

1. Introduction

Among the various threats and challenges facing mankind today, perhaps the most formidable and menacing one, is air pollution. A World Bank report released recently (2005) states that more than 40,000 people die prematurely every year in India because of health problems related to air pollution. Air pollution is an additional risk factor that increases the statistical probability of death and other adverse health effects caused primarily by cardio- vascular and respiratory diseases (European commission, 2005). New Delhi has the dubious distinction of being the fourth most polluted city in the world [Satyaramchander.A, 1997]. In recent years due to the health and environmental concerns many municipalities particularly in industrialized nations have been forced to assess their Solid Waste Management programs and examine its cost effectiveness in terms of collection, transportation, processing and landfill [Koushki.P, Hulsey.J, Bashaw.E, 1996]. Vehicular emissions are influenced by the combinations of parameters like vehicle technology, fuel quality, vehicle maintenance, driving patterns and traffic controls [Santosh A Jalihal and T. S. Reddy., 2006].

The MSW vehicles substantially add atmospheric pollution in addition to the solid waste generated from the city. As there are only limited studies on the emission loading of MSW vehicles, there is a need to study and quantify the emission on the environment generated by these diesel vehicles. The present work focuses on the emission of various gases into environment due to the collection and transportation of MSW carrying vehicles in the area of Coimbatore City situated in the state of Tamil Nadu, southern part of India. In this paper a model has been developed to quantify the emission generated by these vehicles. This model was applied for disposal of wastes to the proposed composting and recyclable yard in Coimbatore city. The emissions generated by these MSW vehicles were predicted by forecasting the population upto the year 2020.

2. Disposal of Solid Waste - A Scenario

The Coimbatore city has a population of 10,93,888 with an aerial extent of 105.6 Sq km, produce MSW of 564 tons per day as per the census 2004 (Commissioner of Municipal Administration, India**,** 2000). This excludes the construction debris and industrial waste. It has very poor solid waste management practices. The entire city with 72 wards is divided into four zones namely North, South, East and West. It is estimated that per capita solid waste generation by Coimbatore dwellers is about 515 gms per day. The unsegregated MSW collected in the different zones of the city is being dumped on open places. In most of the places the wastes are thrown in and around the bins. At present unrecognized rag pickers are involved in the collection of recyclable fractions from the different parts of the city and also from the unsanitary landfills.

At present, the entire hygiene of the city relies on the efficiency of the collection system and conversion techniques used. The number of dumping sites in the city is four, but only one site is in operation at Vellalur that covers an area of 604 acres. Other sites are currently not in use. The wastes are collected through open body trucks and are dumped on the recognized open dumping sites, i.e. unsanitary landfills. Table 1 refers to the total number of owned and hired vehicles for the purpose of collection and transportation of MSW to the dumping yard of Coimbatore [Commissioner of Municipal Administration, India, 2000]. It is inferred from the Table 1 that more number of diesel vehicles are utilized for carrying MSW. In the state of Kuwait seven private companies are incharge of collection, transportation, disposal of household wastes and its cost accounts to $24.00 per ton of waste. Public complaints regarding this service are non-existent or rare [Koushki.P.A, U.Al.Duraij , W.Al-Ghimlas, 2004]. The quantity of zone wise wastes generation of MSW and the corresponding population statistics are given in Table 2 (Commissioner of Municipal Administration, India, 2000).

The waste prognosis is mainly based on the income level, life style, population growth, life expectancy rate, mortality rate of the people in the city etc.., But no studies were conducted for the prognosis of waste in Indian cities. Hence in this paper the waste is predicted based on the per capita solid waste and population growth of the city. Figures 1and 2 shows the total quantity of waste generated by the Coimbatore dwellers for degradable and recyclable waste respectively upto the year 2020.

3. Methods adopted in Developing Models

3.1 Traffic studies

To estimate the load of pollutants, it is necessary to estimate the speed of the vehicle travelled with time interval on Coimbatore roads during collection and transportation of MSW. In order to accomplish these estimates, extensive traffic studies were carried out on the road network of Coimbatore city. The traffic studies were designed and conducted to quantify the emission load on atmosphere particularly by these diesel vehicles. An analysis was carried out to calculate the emissions generated by diesel vehicles carrying MSW to obtain the different modes of speed and time interval during different hours of the day. Twelve different samples were randomly chosen for different time intervals of the day.

Employing these data, weighing factor for the different speeds of the vehicle was calculated. The speed of the vehicle was converted into engine rpm by choosing the respective gear ratios.

3.2 Model Development

Based on the experimental interpretations, the following model has been developed by the author to calculate the emissions generated by diesel vehicles during the collection and transportation of MSW. The weighing factor for the different speeds of the vehicle was calculated using the following equation

$$W_{ij} = \frac{t_{ij}}{T} \qquad (1)$$

so that W_{ij} = 1 for

i=10, 20, ……60

j=10, 20, …….60

Where

W_{ij} = Weighing factor for the i^{th} to j^{th} speed step of the vehicle.

t_{ij} = Duration in which the vehicles travel from i^{th} to j^{th} speed step in seconds

T = Total time travelled by the vehicle in seconds.

Measuring direct vehicle emissions for different road speeds is a difficult task. Hence the speed of the vehicle is transformed to engine rpm using the relation

$$N = \frac{S(2.65 \times G)}{R} \tag{2}$$

Where

N = Number of revolutions per minute

S = Speed of the vehicle in km/hr

G = Gear ratio for different speeds of the vehicle

R = Radius of the vehicle tyre in metre.

For the corresponding engine speed and load condition, the emission exhausted by the engine was measured using the engine test beds and gas analysers, which in turn weighed as follows,

$$(CO)_T = \sum_{i=0}^{60} W_{ij}(CO)_i \tag{3}$$

$$(CO_2)_T = \sum_{i=0}^{60} W_{ij}(CO_2)_i \tag{4}$$

$$(HC)_T = \sum_{i=0}^{60} W_{ij}(HC)_i \tag{5}$$

$$(NO_x)_T = \sum_{i=0}^{60} W_{ij}(NO_x)_i \tag{6}$$

Where,

$(CO)_i$, $(CO2)_i$, $(HC)_i$, and $(NO_x)_i$ are the emissions in gm/cycle and

$(CO)_T$, $(CO_2)_T$, $(HC)_T$ and $(NO_x)_T$ are the total emissions in gm/cycle respectively during the generating cycle.

4. Model application for Coimbatore City

Emission load on disposal of waste are analysed for the city of Coimbatore. The source-segregated waste is recommended to collect separately by placing two bins for two different waste such as degradable and recyclable. In this case two separate vehicles are considered for collection and transportation of these wastes to the respective treatment yards. In the first case, emission load of pollutants into the atmosphere for the degradable wastes to the proposed Vellalur Composting yard is analysed. In the second case, it is analysed when the recyclable waste are disposed separately to the Ukkadam recyclable treatment yards.

4.1 Collection and Transportation of MSW

Collection and Transportation of MSW include the

- Collection of segregated wastes such as degradable and recyclable fractions in an urban area
- Transportation of the collected waste to the respective processing facilities

4.1.1 Collection of MSW

The collection time in the city takes nearly two hours for each trip. It involves frequent stopping and starting of vehicles and running the vehicle at non-optimal speeds. This leads to more fuel consumption of the vehicle. The expenditure on collection of waste alone amounts to 45-75% of total solid waste management system, in manual intensive system, which is being adopted in India and other developing countries. It is necessary to pay attention to this aspect in order to improve and provide services at a lesser cost. [Kapil.P.Devang, 2006]. Thirty to forty percent of the waste is left uncollected in streets. This is due to the non-availability of sufficient transportation of fleet, frequent breakdown of vehicles and absenteeism of the crew. Part of the waste is being disposed by open burning. The emission load of pollutants due to open burning of MSW for Tamilnadu is growing at the rate of 3 tons/year [Chnahi Sinha, 1997]. Figure.3 shows the average vehicular speed for the collection of MSW.

From the observed data, only 10% of the time, engine of the vehicle was not in running conditions. Also from the graph it was predicted that collection vehicle travels at an average speed of 14.5 km/hr. Thus total distance covered by the vehicle during collection in km per year D_{ct} was calculated using the following equation

$$D_{ct} = N \times D_c \tag{7}$$

$$Dc = 0.9 \times \sum_{i=0}^{60} [t_i \times S_c]$$

where,

D_c = Total distance covered in Km per trip.

N = Total number of trips per year.

t_i = Total collection time per trip and

S_c = Speed of MSW vehicles in km per hr during collection of wastes.

4.1.2 Transportation of MSW

Coimbatore Corporation is planning to supply 100 tons of biodegradable waste and 30 tons of recyclable waste per day to the private entrepreneurs for the composting and recycling respectively. This proposal is under process. Figure 4 shows the average vehicular for the transport of MSW.

The total fleet of vehicles used in a day depends on the total MSW generated in a city and the vehicles hauling capacity, number of bins and collection frequency. Trucks are designed to carry 5-7 tons of building material of large density, but the MSW is lighter and hence the truck actually carries only 3 tons of MSW. Total distance travelled, during transportation in km/year, expressed as D_t , could be worked from the following relationships

$$D_t = \sum_{i=}^{4} [MSW_g \div C] \times [T_t]_i \tag{8}$$

Where,

MSW_g = Total municipal solid waste generated in tons for four zones of the city

C = Hauling capacity of the vehicles in tons per trip.

T_t = Travelling distance of vehicle during transportation in km per trip for four zones of the city.

The total distance travelled by the vehicle was calculated to estimate the emission loading into the environment. The total distance travelled by the vehicle for disposal of the waste is calculated using the equations (7) and (8). Figure 5 predicts the emission of various pollutants such as CO, CO_2, HC and NO_x for different rpm of engines. From these figures, emissions are interpolated for different average engine rpm of MSW carrying vehicles. Thus the total emission load was estimated using the equations 3-6.

5. Results and Discussion

The suggested model in this paper can be applied to urban and rural areas to quantify the emissions generated by MSW carrying vehicles. It also helps the decision makers in waste management system to understand the Greenhouse gases released due to vehicle pollution in MSW management sector. The risk of global warming is intensified by the CO_2 emissions of increasing activities of the transport sector.

The amount of CO, CO_2, HC, and NO_x emissions generated during the collection and transportation of the disposal of wastes for the existing situation and the proposed composting yard for the degradable fractions are same. This is due to the lesser quantity of the generation of the recyclable fractions. The total distance travelled by the vehicle to dispose the degradable fraction to the composting yard is 24.84 times higher than recyclable fractions to the recycling yard. This is mainly due to more generation of the degradable fractions than the recyclable fractions by the residents. It is found that generation of the degradable and recyclable fractions are 94% and 6% respectively by the Coimbatore dwellers. All the emissions generated during the collection of the degradable fraction are 3.06 times lesser than collection of recyclables. Also CO, CO_2, HC, and NO_x emissions during collection of degradable wastes are 1.77, 2.29, 2.95 and 3.00 times higher than transportation of the same to the compost yard.

Figure 6-9 shows the emissions generated exclusively by the MSW vehicles up to the year 2020. This shows that the emissions are increasing every year due to the generation of more quantity of waste. The waste management sector emphasis 3R policies i.e., Reduction, Reuse and Recycling of the waste. This reduces transportation used for disposal of MSW and thereby reducing CO_2 emissions.

6. Conclusion

From the experimental studies and with the help of the model predictions, the following observation has been suggested to reduce the emission of Greenhouse gases.

1) The total distance travelled by the vehicle during collection can be reduced by the optimisation of collection routes and also implementation of 3 R policies, thus releasing lesser emission load.

2) The body of the MSW vehicle can be modified based on the bulk density of the waste.

3) Source sorted wastes from the households can be collected through pushcarts to reach the community bin and

4) Vehicles with two separate compartments to collect degradable and recyclable waste fractions can be considered to reduce the total distance travelled by the vehicle.

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Table 1. 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 2. Zone wise of Generation of Solid Waste

Sl.No	Zone	No. of Houses	Population	Garbage Generated in MT/ Day			
				Degradable	Recyclable	Inert	Total
1	East	63,355	2,87,553	102	7.2	22.4	13.6
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	86.8	564

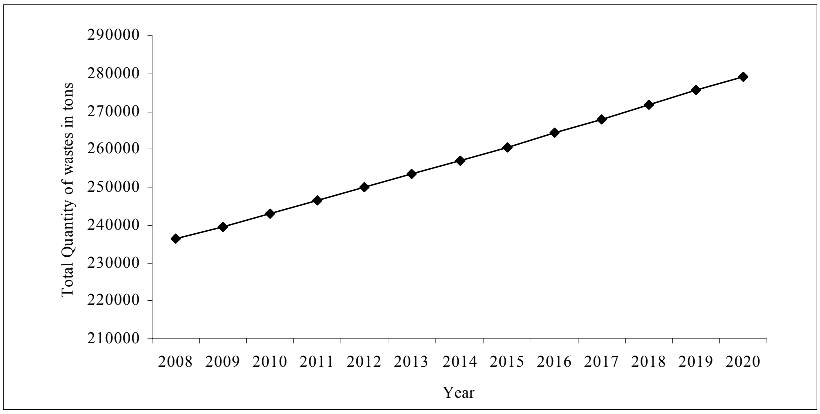


Figure 1. Generation of Total Quantity of Degradable waste

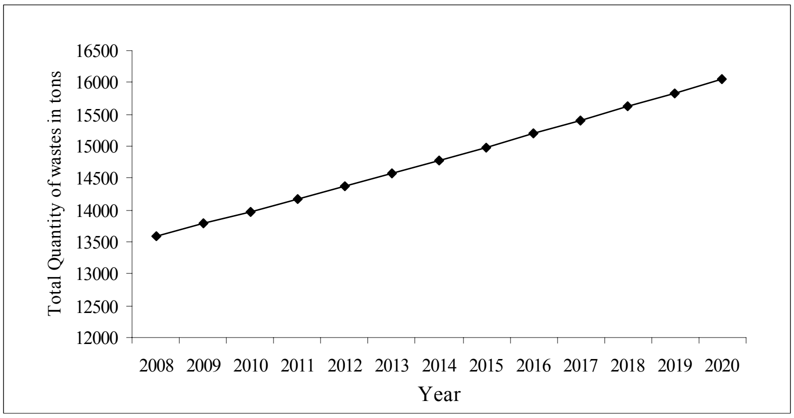
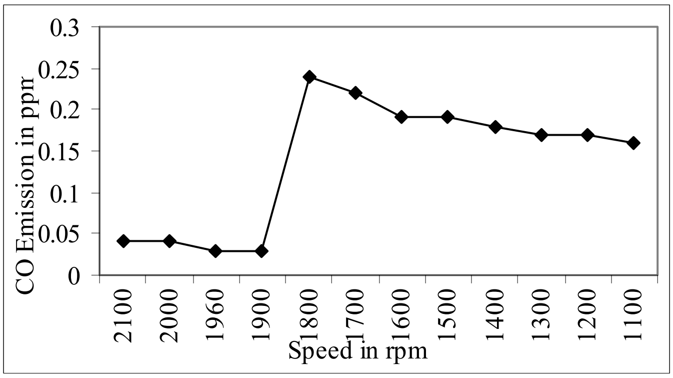
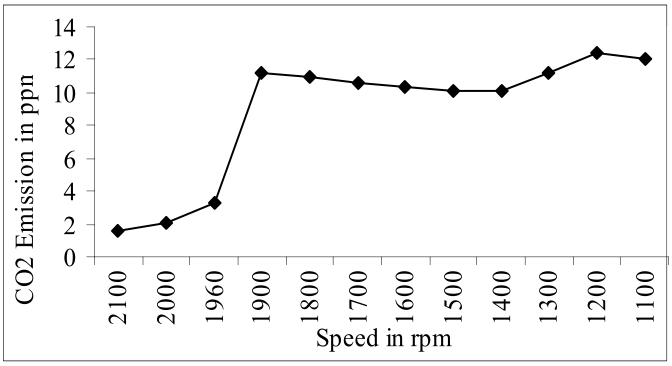


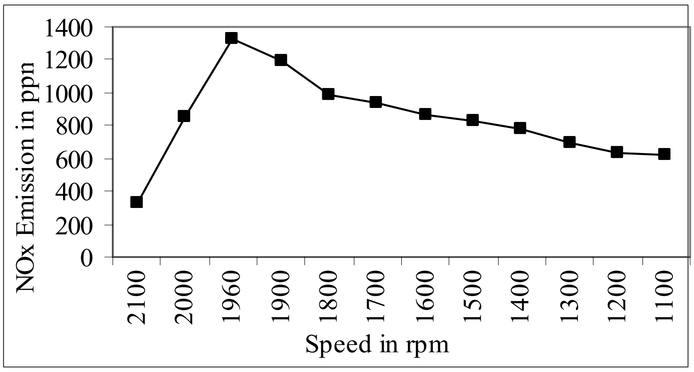
Figure 2. Generation of Total Quantity of Recyclable waste

Figure 3. Average vehicular speed for the transport of MSW

Figure 4. Average vehicular speed for the transport of MSW







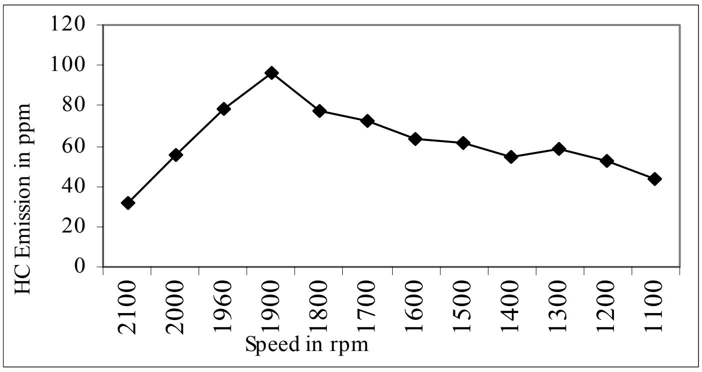


Figure 5. Emission of various pollutants for different rpm of the engine

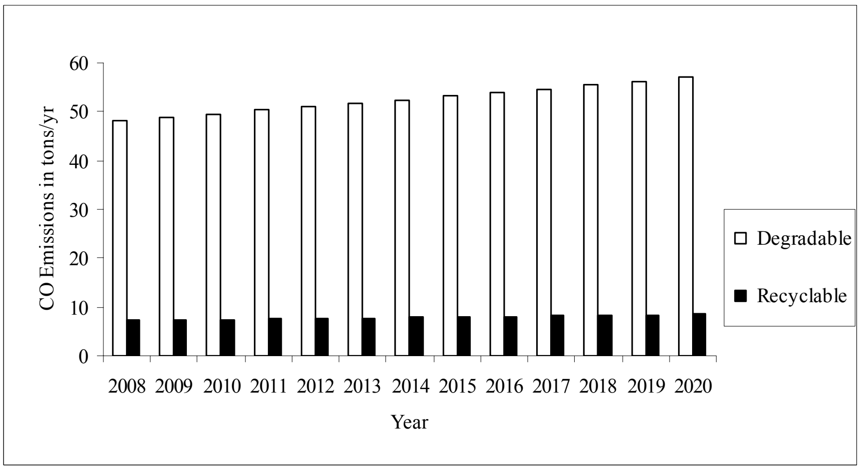


Figure 6. CO Emissions for disposal of Degradable and Recyclable waste

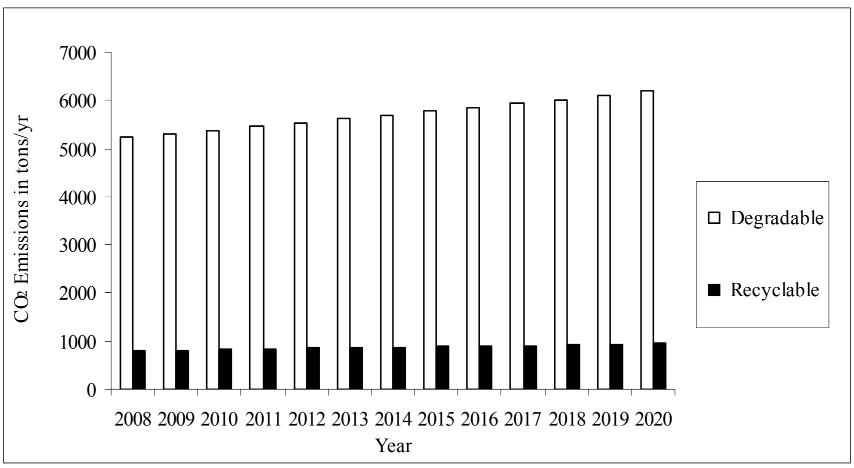


Figure 7. CO_2 Emissions for disposal of Degradable and Recyclable waste

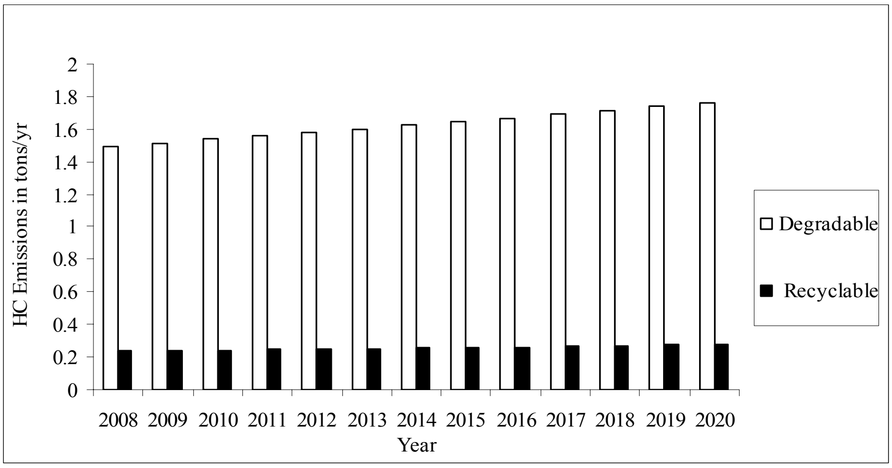


Figure 8. HC Emissions for disposal of Degradable and Recyclable waste

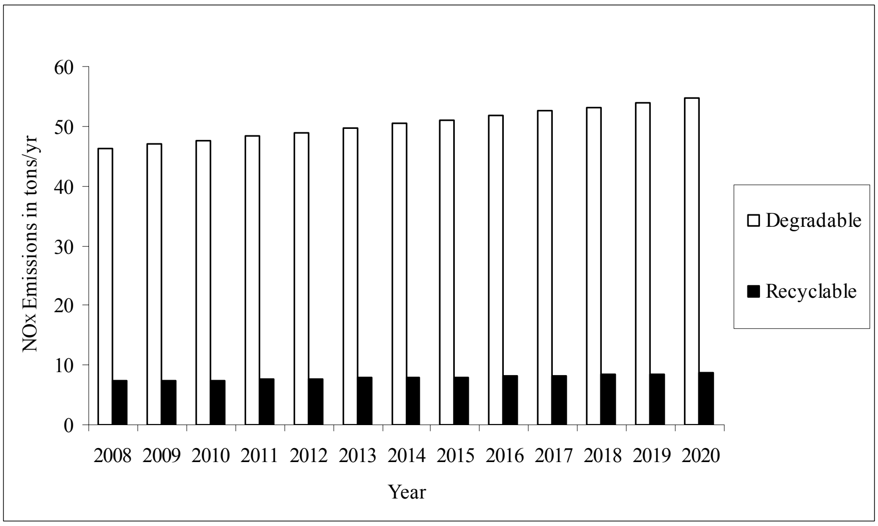


Figure 9. NO_X Emissions for disposal of Degradable and Recyclable waste