Computer Applications to Assess City Municipal Solid Waste for Better Utilization: A Case Study on Internationally Recognized Pilgrimage City, Puri, Odisha, India

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Abstract

Solid wastes are generated from domestics, industries, hotels, temples and other sources etc., dumped in all around the city which creates an environmental pollution. These wastes are known as municipal solid wastes classified in to different types such as recyclable, combustible, biodegradable and landfill etc. Energy from waste (EfW) for non-recyclable wastes is a suitable method of waste management and is important for renewable energy production. In the present investigation, an attempt is made to apply Box–Behnken experimental design and response surface methodology and mathematical software MATLAB 7.1 on municipal solid wastes of internationally recognized pilgrimage town Puri, Odisha, India. The study reveals that Puri town of Odisha is currently recycles 13% of household waste and landfills 48.5% and the remaining 38.5% is biodegradable.The ensured optimum concentration of biodegradable solid wastes available will be 151 MT, optimum combustible (MT): 11and optimum miscellaneous (MT): 83.Energy can be generated and utilized for different purposes by processing the non-recyclable solid wastes. It also helps the human civilization for better health and wealth.

Key words: Solid wastes, Puri, Odisha, Box-Behnken design, Optimization, Response Surface Methodology

“1. Introduction”

Puri located on the East Coast of India overlooking Bay of Bengal, Puri is one of the fastest growing tourist destinations of India. A biocompust plant was set up by the government for managing the solid waste generated in the city. The project was developed for the participation of the public private party [1].

Municipal solid waste (MSW), commonly known as trash or garbage (US), refuse or rubbish (UK) is a waste type consisting of everyday items that are discarded by the public. Solid waste can be classified into different types depending on their source: a) Household waste is generally classified as municipal waste, b) Industrial waste as hazardous waste, and c)

Biomedical waste or hospital waste as infectious waste [2].

Municipal solid waste consists of household waste, construction and demolition debris, sanitation residue, and waste from streets. This garbage is generated mainly from residential and commercial complexes. With rising urbanization and change in lifestyle and food habits, the amount of municipal solid waste has been increasing rapidly and its composition changing. Municipal solid waste (MSW) includes degradable (paper, textiles, food waste, straw and yard waste), partially degradable (wood, disposable napkins and sludge, sanitary residues) and non-degradable materials (leather, plastics, rubbers, metals, glass, ash from fuel burning like coal, briquettes or woods, dust and electronic waste).

Environmental degradation impacts the society. The urban poor, who do not have a fair access to public health and sanitary services in the city, they are subject to extremely unhygienic conditions in their settlements and periodic outbreaks of water and air borne epidemics. Garbage generated in households can be recycled and reused to prevent creation of waste at source and reducing amount of waste thrown into the community dustbins.

The mean value of the quantity of solid waste production in this period per year was 683,423,575 kg. The corresponding percentage per citizen per year was estimated at 646.07 kg or 1.77 kg per citizen per day. It was also found that the 5 largest municipalities of the urban area of MUTGA also produce the largest quantities of solid waste per year [3]

The increase in population, the rapid economic growth and the rise in community living standards accelerate municipal solid waste (MSW) generation in developing cities. This problem is especially serious in Pudong New Area, Shanghai, China. The daily amount of MSW generated in Pudong was about 1.11 kg per person in 2006 [4]. According to the current population growth trend, the solid waste quantity generated will continue to increase with the city’s development. In this paper, we describe a waste generation and composition analysis and provide a comprehensive review of municipal solid waste management (MSWM) in Pudong. Some of the important aspects of waste management, such as the current status of waste collection, transport and disposal in Pudong, will be illustrated. Also, the current situation will be evaluated, and its problems will be identified.

Municipal solid waste (MSW) refers to household waste combined with a minor portion of commercial waste collected together. It is regarded as a source of renewable energy because it contains a high proportion of biomass materials such as paper/cardboard, wood, and food. From the perspective of sustainable waste management, the priority is on the reduction of waste generation followed by material recycling, both of which are highly beneficial in terms of greenhouse gas (GHG) emissions reduction [5] by saving resources otherwise required for manufacturing new products.However, some wastes are not suitable for recycling. For the non recyclable fractions, an energy recovery method becomes essential because it can reduce the use of fossil fuels. At the same time, it can also minimize the environmental and health problems of waste disposal, unlike the landfill alternative. The conventional technology for energy from waste (EfW) is direct combustion (incineration), but advanced technologies such refuse-derived fuel (RDF) production, gasification, and anaerobicdigestion are also available. In using the energy produced from waste, combined heat and power (CHP) is the preferred option for maximizing overall energy efficiency.

The study would be helpful for improving the decision quality for choosing the municipal solid waste treatment system [6].

Solid Waste Management is an integral part of the Environment Management of each city. Due to rapid growth of urban population, as well as constraint in resources, the management of municipal solid waste poses a difficult and complex problem for the society and its improper management gravely affects the public health and degrades environment. By 2025 it is expected that urban population shall reach 50% of total population and the problem also shall increase further. Analysis across countries reveals that generation of MSW is positively related to variation in per capita income and with population size. At present in many large cities developed countries less than 70% of MSW are collected and 50% of households are served [7].

Agricultural application of Municipal Solid Waste (MSW), as nutrient source for plants and as soil conditioner, is the most cost effective option of MSW management because of its advantages over traditional means such as land filling or incineration. However, agricultural application of MSW can lead to a potential environmental threat due to the presence of pathogens and toxic pollutants. Composting is an attractive alternative of MSW recycling. Application of MSW compost (MSWC) in agricultural soils can directly alter soil physicochemical properties as well as promote plant growth. The soil microbial biomass, considered as the living part of soil organic matter, is very closely related to the soil organic matter content in many arable agricultural soils. Numerous studies, with different MSWC amendment doses on different soil types and under different water regimes revealed no detrimental effect on soil microbial biomass. In this review, we show the state of art about the effects of MSWC amendment on soil microbial mass [8].

This paper provides an overview of the trend of generation, composition, and management of municipal solid waste [9], and estimates the carbon emissions arising from municipal solid waste management in Beijing. The correlation analysis conducted shows that the generation of municipal solid waste in Beijing has been growing steadily, showing high correlations ($r > 0.9$) to the total GDP, per capita income, and the population. Food waste showed an increasing trend since 1990. Compared with the results of an investigation in 1990, ash and woodchips content in 2003 declined from 56% to 17%, while the percentage of paper and plastic increased from 10% to 29% over the same period. The calorific value of the municipal waste also increased, from 2,686 kJ/kg in 1990 to 4,667 kJ/kg in 2003, indicating that the waste is suitable for incineration. Currently, the source separation ratio of municipal waste is approximately 15%. About 94% of all the collected solid waste goes to the landfill while 4% is composted and 2% is incinerated. A moderate garbage collection fee is applied to both permanent and temporary residents in Beijing, but the willingness to pay for solid waste collection and treatment is still low. Under current treatment mode, the total amounts of carbon emission from waste disposal sites and incineration increased with the increase of municipal solid waste, from 29.8 Gg in 1990 to 84.5 Gg in 2003, including 83.3 Gg of CH_4 and 22.0 Gg of CO_2.

In the conventional experimentation method of one-factor-at-a-time, only one factor is varied over its range with other factors remaining constant. The interaction effect of two or more variables cannot be determined using this approach. Optimization of reutilization of solid wastes generated in the city in a conventional way, such as a set of variables like degradable, combustible, recyclable wastes, miscellaneous etc. all accounting to very good numbers of experiments, time consuming and tedious. Box Behnken design ([10], [11], [12], [13], [14], [15], [16]) is a rotatable second-order design based on three-level incomplete factorial designs. For three factors, for example, the design can be constructed as three blocks of four experiments consisting of a full two-factor factorial design with the level of the third factor set at zero ([10], [11]). The RSM also quantifies the relationship between the controllable input parameters and the response surface ([16], [17], [18], [19], [20], [21]). The statistical optimization technique using Response Surface Methodology (RSM) is a useful tool which allows one to obtain appropriate data that can be analyzed to arrive at objective conclusions and determine the optimum conditions through a relatively smaller number of systematic experiments. Several researchers attempted to use Response Surface Method (RSM) on different types of minerals, ores, materials etc. on different types of units operations ([16], [19], [20], [21], [22], [23]).

In the present investigation, Puri with population 2,20,210 (2011) Eastern side is famous for pilgrimage and one of the four religious Dhams on the seashore of Bay of Bengal has been considered for examination and for determination of best conditions of treatment through response surface methodology and mathematical software Mat LAB 7.1 on Municipal Solid Waste Management. It is used to find out the optimum amount of solid waste can be recycled and bi degradable.

“2. Materials and methods”

The solid wastes were collected from the different locations of Puri district of Odisha state. These data were collected in each year from 2001 to 2011. These wastes were separated in three different types as three variables such as degradable, combustible and miscellaneous (others). The requirements for the Box_Behnken design with response surface method and their applications to the design of experiments and modeling of the treatment of solid wastes are described. Optimization of these variables for maximum utilization of solid wastes is achieved using quadratic programming of the mathematical software package Matlab7.

2.1 Statistical design and modeling using Response Surface Methodology (RSM)

Response surface methodology (RSM) is a collection of statistical and mathematical methods that are useful for modeling and analyzing engineering problems. In this technique, the main objective is to optimize the response surface that is influenced by various process parameters. The RSM also quantifies the relationship between the controllable input parameters and the response surface obtained (Kwak, 2005; Aslan and Cebeci, 2007; Aslan, 2007a, 2007b).

The design procedure of RSM is based on the following

1. Designing of experiments for adequate and reliable measurement of the response.

2. Developing a mathematical model of the second – order response surface with the best fitting.
3. Finding the optimal set of parameters that produce a maximum or minimum value of response.
4. Representing the direct and interactive effects of process parameters through two or three dimensional plots.

If all variables are assumed to be measurable then the response surface can be expressed as:

$$\boldsymbol{y = f\,(x_1, x_2, x_3 \cdots\cdots\cdots\, x_k)} \quad \text{-----------------} \ \textbf{(1)}$$

where y is the output and x_i the variables of action called factor

The goal of this aspect of the study was to optimize the response variable y. The independent variables are assumed to be continuous and controllable by the experiments with negligible errors. A reasonable approximation for the true functional relationship between independent variables and the response surface is desired. A second-order model is usually used in response surface methodology (Gunaraj and Murugan, 1999; Kwak, 2005; Aslan and Cebeci, 2007; Aslan, 2007a, 2007b):

$$\boldsymbol{y = \beta_0 + \sum_{i=1}^{k} \beta_i\, x_i + \sum_{i=1}^{k} \beta_{ii}\, x_i^2 + \sum_{i=1}^{k-1} \sum_{j=2}^{k} \beta_{ij} x_i\, x_j + \varepsilon} \quad \text{-------------------------} \ \textbf{(2)}$$

where x_1, x_2,…, x_k are input factors which influence the response y; β_0, β_{ii} (i=1, 2, …, k), β_{ij} (i=1, 2, …, k; j=1, 2, …, k) are unknown parameters and ε is a random error. The β coefficients, which should be determined in the second-order model, are obtained by the least square method. Generally equation (2) can be written in matrix form (Kincl et al., 2005; Kwak, 2005; Aslan and Cebeci, 2007; Aslan 2007a, 2007b):

$$\boldsymbol{Y = bX} + \in \quad \text{-------------------------} \ \textbf{(3)}$$

where Y is defined to be a matrix of measured values, X to be a matrix of independent variables. The matrices b and ∈ consist of coefficients and errors, respectively. The solution of equation (3) can be obtained by the matrix approach

$$\boldsymbol{b} = (\boldsymbol{X'X})^{-1}\boldsymbol{X'Y} \qquad \text{------------------} \qquad \textbf{(4)}$$

where X′ is the transpose of the matrix X and $(X'.X)^{-1}$ is the inverse of the matrix X′.X ([17], [19], [20]).

The coefficients, i.e. the main effect (b_i) and two factors interactions (b_{ij}) can be estimated from the experimental results by computer simulation programming applying the least squares method using MATLAB 7.1.

2.2 Experimental design for reutilization solid wastes

Box-Behnken three-level factorial design was chosen to find out the relationship between the response function (treatment of solid wastes for utilisation) and three variables of the solid wastes. Design Expert v.7 statistical software (Stat ease Inc.) was used for the analysis of the experimental data and for statistical modeling. The three factors investigated were: (i) degradable, (ii) combustible and (iii) miscllaneous by x_1, x_2 and x_3 respectively. Each factor was run at two levels and the intermediate response was assumed to be linear, which is necessary for Box-Behnken three-level factorial designs. The high and low levels for each factor were given in Table 1.

Box-Behnken design requires an experiment number according to $N = k^2 + k + c_p$, where k is the factor number and c_p is the replicate number of the mid-point ([10], [15], [24], [25]). Box_Behnken is a spherical, revolving design. Viewed as a cube (([10], [11], [24]), the Box– Behnken design consists of a central point and the middle points of the edges. However, it can also be viewed as consisting of three interlocking 2^2 factorial designs and a central point ([10], [15], [24], [25]). Seventeen experimental runs in total were needed (Table 2) for three levels, three factorial Box-Behnken experimental designs. The possibility of non-linearity within the design space has been accounted for through the introduction of centre points and model augmentation. The centre points are essentially used to test for evidence of pure second-order or quadratic effects in the response region of exploration.

The high and low levels for each factor (Table 1) were chosen on the basis of preliminary trials. These high and low levels are expressed in coded form as -1 and +1, respectively to convert the absolute quantity into a dimensionless quantity making the handling of the experimental data convenient. All variables used in the model are normalized to vary in this way; the relative change of a variable is directly related to the size of its regression coefficient.

Considering the effects of the main factors and also the interactions between two-factor sets, equation 2 takes the form:

$$\boldsymbol{y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{33} x_3^2 + \beta_{12} x_1 x_2 + \beta_{13} x_1 x_3 + \beta_{23} x_2 x_3} \text{ ------- } \mathbf{(5)}$$

where y is the predicted response, β_0 is a model constant; x_1, x_2 and x_3 are independent variables; β_1, β_2 and β_3 are linear coefficients; β_{12}, β_{23} and β_{13} are cross product coefficients; and β_{11}, β_{22} and β_{33} are the quadratic coefficients ([11], [16], [26]).

The coefficients, i.e. the main effect (β_i) and the two factor interactions (β_{ij}), were estimated from the experimental results by computer-simulation programming applying the least square method using MATLAB 7.1.

"3.results and discussions"

3.1 Waste Management in Puri

Table 3 presents the status of waste management in Puri in different years. Over 33.62 MT to 47 MT of waste was generated in Puri city, of which more than one third was degradable waste. The amount of metals is 0.53 MT to 0.75 MT, plastic is of 1.23 MT to1.75 MT waste and textile is generated of 2.1 MT to 2.91 MT. Paper is generated around 0.88 MT to 1.25 MT, whereas 0.7 MT to 1.0 MT glass is generated. Pother wastes are varying from 16.98 MT to 24.25 MT. It is observed from Table 4that thirteen percent (4.55 Mt to 6.5 MT) of solid waste is currently being recycled, 38.5% (13.48 MT to 19.25 MT) is biodegradable, and 48.5% (16.98 MT to 24.25 MT) is landfilled. The waste generated in the city is shown in Figure 1.

3.2 Design Matrix

A three-factor three level Box–Behnken design was used to determine the responses of reutilization of solid wastes as recycle, biodegradable and landfill. Three significant variables of treatment of solid wastes are degradable (MT), combustible (MT) and miscellaneous (MT). If the number of tests at the central points is three, the total number of tests required for the three independent variables comes out to be $3^2+3+5=17$ for Box–Behnken design. Independent variables and their coded/actual levels used in this study are tabulated in Table 2. For the three-level three-factorial Box– Behnken experimental design, a total of 17 experimental runs are needed. Using the relationships in Table 2, coded/actual levels of the variables for each of the experiments in the design matrix are calculated as given in Table 1.From the experimental results listed in Table 2 and equation (4), the second-order response functions representing the treatment for utilization of the solid wastes could be expressed as functions of the degradable (MT), combustible (MT) and miscllaneous (MT) of the solid wastes. The relationship between response and variables was obtained for coded unit as follows: treatment of solid waste for recycle process:

$$y_1 = +5.53 + 0.44 * x_1 - 0.072 * x_2 + 0.46 * x_3 + 0.19 * x_1^2 - 0.05 * x_2^2 - 0.15 * x_3^2 - 0.048 * x_1 * x_2 + 0.15 * x_1 * x_3 - 0.20 * x_2 * x_3 \text{ ------------------(6)}$$

Equation 6 is derived from equation 5 for the response factors Equation 6 was for recycle of solid wastes, from which the response factors at any regime in the interval of our experiment design can be calculated from this equation. The observed (experimental) results and the predicted values obtained using these model equations are given in Table 2 and shown in Figure 2. The predicted values and the observed data points, was indicating a very good fit (R^2 value of 0.89 for recycle of the solid wastes for the response equation. The relationship between response and variables was obtained for coded unit as follows: solid wastes can be a biodegradable:

$$y_3 = +16.36 + 1.30 * x_1 - 0.22 * x_2 + 1.37 * x_3 + 0.58 * x_1^2 - 0.14 * x_2^2 - 0.43 * x_3^2 - 0.15 * x_1 * x_2 + 0.43 * x_1 * x_3 - 0.58 * x_2 * x_3 \text{ ---(7)}$$

Equation 7 is derived from equation 5 for the response factors [Equation 7 for biodegradable solid wastes], from which the response factors at any regime in the interval of our experiment design can be calculated from this equation.

The observed (experimental) results and the predicted values obtained using these model equations are given in Table 2 and shown in Figure 3. The predicted values and the observed data points, are indicating a very good fit (R^2 value of 0.89 biodegradable solid wastes for the response equation.

The relationship between response and variables obtained for coded unit are as follows: solid wastes can be used as landfill:

$$y_3 = +20.61 + 1.63 * x_1 - 0.15 * x_2 + 1.85 * x_3 + 0.61 * x_1^2 - 0.055 * x_2^2 - 0.42 * x_3^2 - 0.18 * x_1 * x_2 + 0.55 * x_1 * x_3 - 0.47 * x_2 * x_3 \text{ -----------------------------(8)}$$

Equation 8 is derived from equation 5 for the response factors [Equation 8 for the solid wastes] can be utilized as landfill, from which the response factors at any regime in the interval of our experiment design can be calculated from this equation. The observed (experimental) results and the predicted values obtained using these model equations are given in Table 5 and shown in Figure 4. The predicted values and the observed data points are indicating a very good fit (R^2 value of 0.87) for solid wastes utilized as land fill for the response equation.

3.3 Optimization of variables of recycle

One of the main aims of this study was to maximize the recycle of the solid wastes of Puri, Odisha and find the optimum operation conditions from the mathematical model developed. Optimization of the process variables of the recycle of the solid wastes, biodegradable of the solid wastes and solid wastes utilized as landfill could be obtained using quadratic programming of the mathematical software package (MATLAB 7.1).

The operation variables for recycle of the solid wastes as determined are:

- ❖ Optimum concentration of degradable (MT): 16.00
- ❖ Optimum combustible (MT): 2.98
- ❖ Optimum Miscellaneous (MT): 27.45

The operation variables used as biodegradable of the solid wastes as determined are:

- ❖ Optimum concentration of degradable (MT): 16.00
- ❖ Optimum combustible (MT): 2.98
- ❖ Optimum Miscellaneous (MT): 19.44

The operation variables for the solid wastes utilized as landfill determined are:

- ❖ Optimum concentration of degradable (MT): 16.00
- ❖ Optimum combustible (MT): 2.98
- ❖ Optimum Miscellaneous (MT): 22.02

In order to gain a better understanding of the results, the predicted models were presented in Figures. 5-7 as 3D (three-dimensional) response surface plots. The data in indicates that the maximum waste from degradable is recycled. Both the combustible and degradable wastes generated which gives the maximum amount of recycle at degradable waste as compared to combustible waste.

"4.conclusions"

Solid wastes generated from different places are dumped all over the town in internationally recognized pilgrimage town Puri, Odisha, India. The following are the conclusions are drawn based on the three levels Box – Behnken factorial design combined with response surface methodology and mathematical software MATLAB 7.1.

- ❖ The predicted and actual values for all responses show good agreement.
- ❖ Optimum concentration of degradable (MT): 16, optimum combustible (MT): 2.98, optimum miscellaneous (MT): 27.45.
- ❖ The operation variables used as biodegradable of the solid wastes as determined are:
- ❖ Optimum concentration of degradable (MT): 16, optimum combustible (MT): 2.98, optimum miscellaneous (MT): 19.44.
- ❖ The operation variables for the solid wastes utilized as landfill determined are:
- ❖ Optimum concentration of degradable (MT): 16, optimum combustible (MT): 2.98, optimum miscellaneous (MT): 22.02
- ❖ The predicted and actual values for all responses show good agreement. The solid wastes can be reutilized after processing for different purposes. The process helps to protect from environmental pollution. Energy can be utilized for different purposes by processing the non-recyclable solid wastes. It also helps the human civilization for better health and wealth.

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“**Table 1**. List of variables at different levels”

Si. No.	Variables	Levels		
		Low (-1)	Center (0)	High (+1)
1	Degradable, MT (x_1)	11.20	13.66	16.00
2	Combustible, MT (x_2)	2.98	3.49	4.00
3	Miscellaneous, MT (x_3)	19.44	23.45	27.45

“**Table 2.** Experimental matrix of the design for factors (according to standard order)”
x_1 = Degradable, x_2= Combustible, x_3 = Miscellaneous

Standard order	Run order	Degradable, MT		Combustible, MT		Miscellaneous,MT		Recycle, MT	Bidegradable, MT	Landfill, MT
		Actual	Coded	Actual	Coded	Actual	Coded			
1	1	13.6	0	2.98	-1	19.44	-1	4.55	13.48	16.98
10	2	13.6	0	4	1	19.44	-1	4.75	14.05	17.7
5	3	13.6	0	3.49	0	23.45	0	5.53	16.36	20.61
12	4	13.6	0	3.49	0	23.45	0	5.53	16.36	20.61
2	5	11.2	-1	2.98	-1	23.45	0	5.33	15.79	19.89
4	6	16	1	2.98	-1	23.45	0	6.11	18.1	22.8
16	7	11.2	-1	3.49	0	19.44	-1	4.94	14.63	18.43
17	8	13.6	0	2.98	-1	27.45	1	6.31	18.67	23.52
13	9	16	1	3.49	0	27.45	1	6.5	19.25	24.25
7	10	13.6	0	3.49	0	23.45	0	5.53	16.36	20.61
14	11	13.6	0	3.49	0	23.45	0	5.53	16.36	20.61
11	12	16	1	4	1	23.45	0	5.92	17.52	22.06
9	13	16	1	3.49	0	19.44	-1	5.72	16.94	21.34
3	14	13.6	0	3.49	0	23.45	0	5.53	16.36	20.61
15	15	11.2	-1	3.49	0	27.45	1	5.14	15.21	19.16
6	16	11.2	-1	4	1	23.45	0	5.33	15.79	19.89
8	17	13.6	0	4	1	27.45	1	5.72	16.94	22.34

“**Table 3.** Waste management of Puri city for different year”

Year	Degradable, MT	Metals, MT	Plastic, MT	Textile, MT	Paper, MT	Glass, MT	Miscellaneous, MT
2001	11.2	0.53	1.23	2.1	0.88	0.7	16.98
2002	11.68	0.55	1.28	2.19	0.91	0.73	17.7
2003	12.16	0.57	1.33	2.28	0.95	0.76	18.43
2004	12.64	0.59	1.39	2.37	0.99	0.79	19.15
2005	13.12	0.62	1.44	2.46	1.03	0.82	19.88
2006	13.6	0.64	1.49	2.55	1.07	0.85	20.61
2007	14.08	0.66	1.54	2.64	1.1	0.88	21.34
2008	14.56	0.68	1.59	2.73	1.14	0.91	22.06
2009	15.04	0.71	1.65	2.82	1.18	0.94	22.8
2010	15.52	0.73	1.7	2.91	1.21	0.97	23.52
2011	16	0.75	1.75	2	1.25	1	24.25

“**Table 4** Responses of waste generated of Puri city for different years”

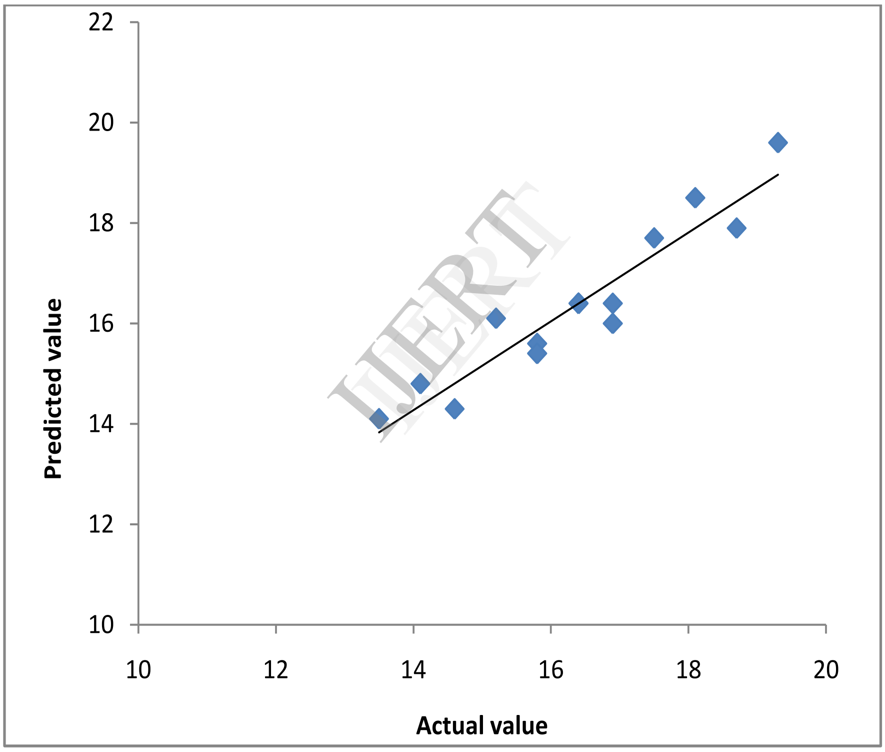
Year	Recyclable, MT	Biodegradable, MT	Landfill, MT	Recyclable, %	Biodegradable, %	Landfill, %
2001	4.55	13.48	16.98	13.00	38.50	48.50
2002	4.75	14.05	17.7	13.01	38.49	48.49
2003	4.94	14.63	18.43	13.00	38.50	48.50
2004	5.14	15.21	19.16	13.01	38.50	48.49
2005	5.33	15.79	19.89	13.00	38.50	48.50
2006	5.53	16.36	20.61	13.01	38.49	48.49
2007	5.72	16.94	21.34	13.00	38.50	48.50
2008	5.92	17.52	22.06	13.01	38.51	48.48
2009	6.11	18.1	22.8	13.00	38.50	48.50

2010	6.31	18.67	23.52	13.01	38.49	48.49
2011	6.5	19.25	24.25	13.00	38.50	48.50

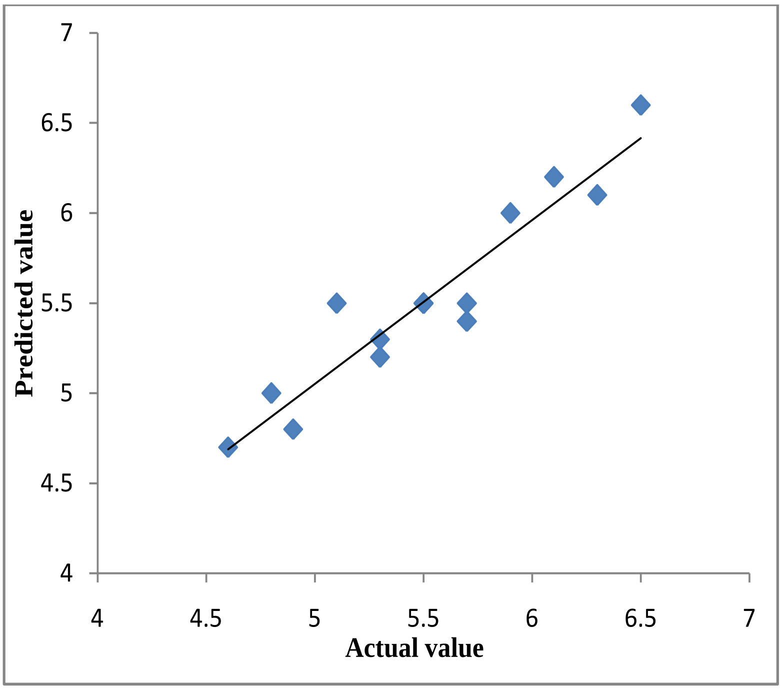
“**Table 5** Actual and predicted values of recycle, biodegradable and landfill uses of solid waste”

Standard Order	Recycle		Biodegradable		Landfill	
	Actual Value	Predicted Value	Actual Value	Predicted Value	Actual Value	Predicted Value
1	5.3	5.3	15.8	15.6	90	90.75125
2	6.1	6.2	18.1	18.5	103.95	102.9888
3	5.3	5.2	15.8	15.4	92.03	92.99125
4	5.9	6.0	17.5	17.7	109	108.2488
5	4.9	4.8	14.6	14.3	92.03	91.1675
6	5.7	5.4	16.9	16.0	108	108.85
7	5.1	5.5	15.2	16.1	98.1	97.25
8	6.5	6.6	19.3	19.6	106.2	107.0625
9	4.6	4.7	13.5	14.1	95.85	95.96125
10	4.8	5.0	14.1	14.8	99.9	99.80125
11	6.3	6.1	18.7	17.9	98.1	98.19875
12	5.7	5.5	16.9	16.4	101.97	101.8588
13	5.5	5.5	16.4	16.4	99.9	99.9
14	5.5	5.5	16.4	16.4	99.9	99.9
15	5.5	5.5	16.4	16.4	99.9	99.9
16	5.5	5.5	16.4	16.4	99.9	99.9
17	5.5	5.5	16.4	16.4	99.9	99.9

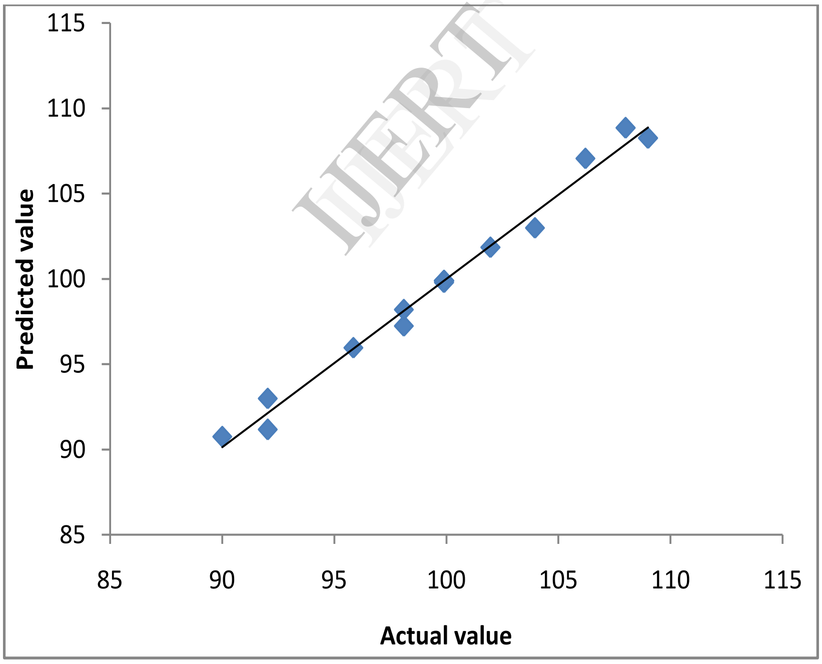
“**Figure. 1** Solid waste generated at Puri city, Odisha”



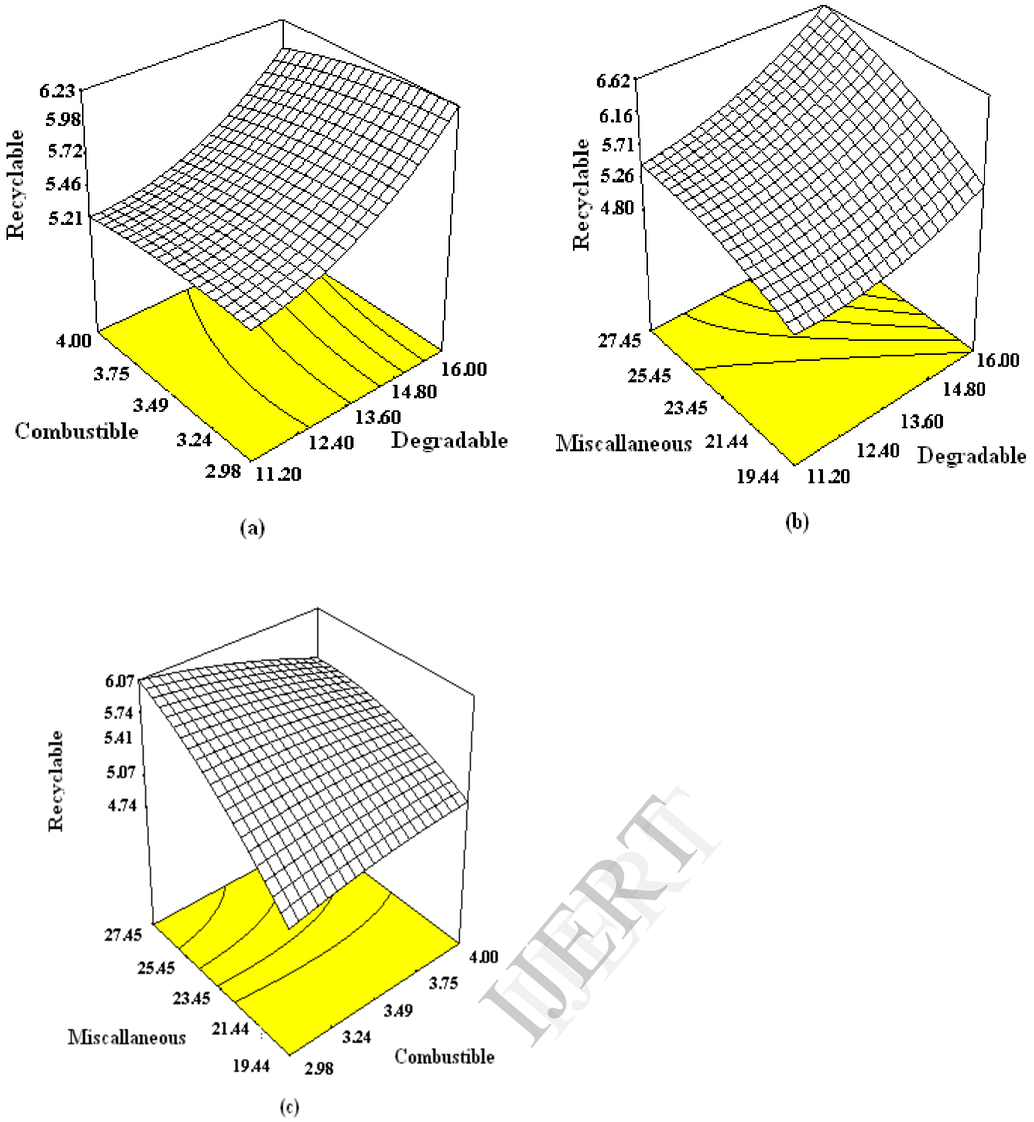
“**Figure. 2** Actual vs. predicted value for recycle response”



“**Figure. 3** Actual vs. predicted value for biodegradable response”



“**Figure. 4** Actual vs. predicted value for landfill response”

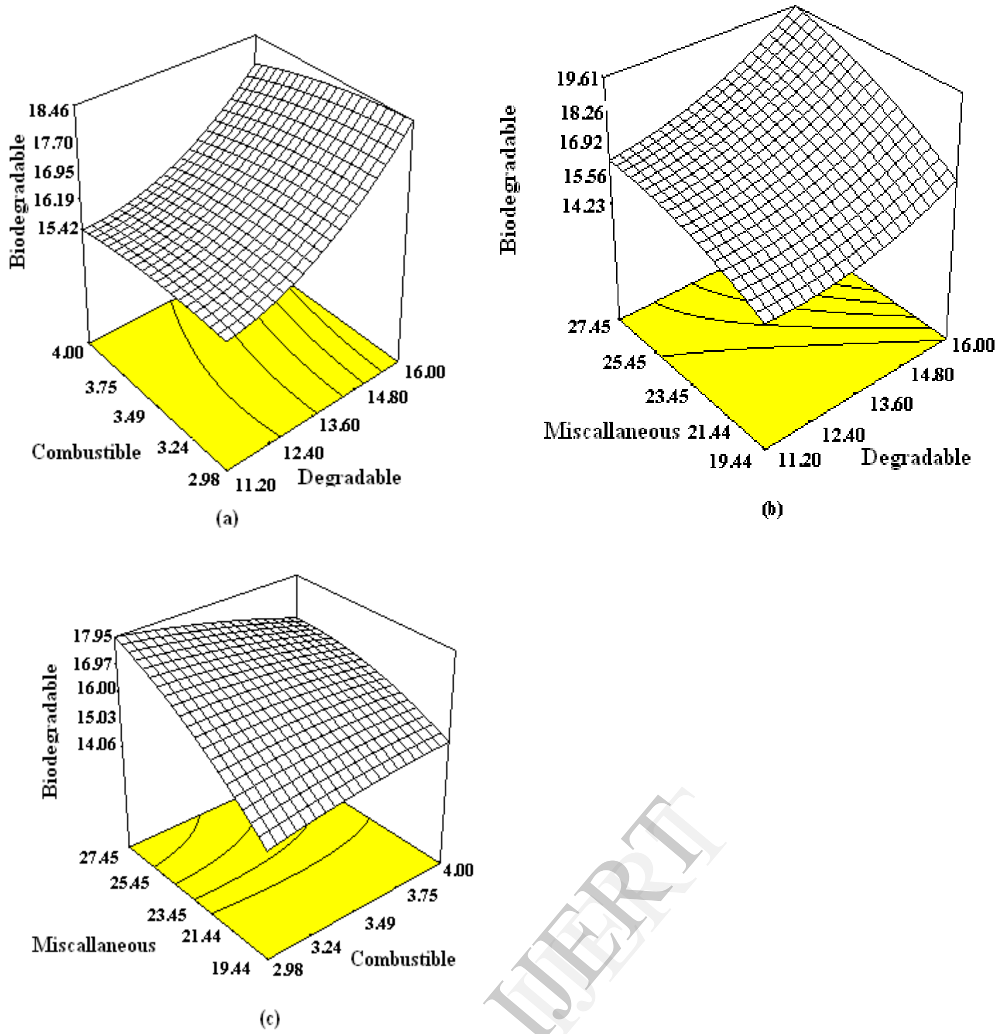


(a)

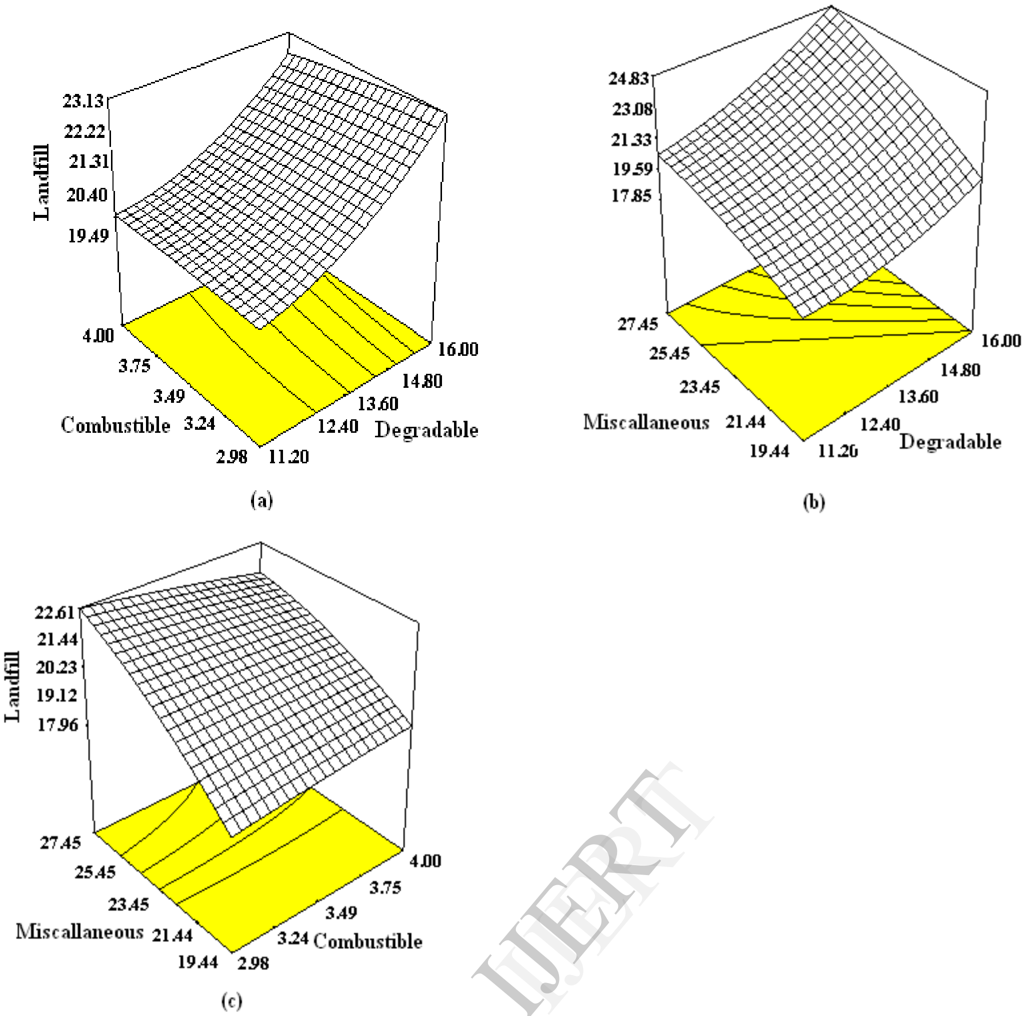
(b)

(c)

“**Figure.5** Response surface plot showing the effects on recycle (MT) of solid wastes for different variables of degradable, combustible and miscellaneous”



“**Figure.6** Response surface plot showing the effects on biodegradable (MT) of solid wastes for different variables of degradable, combustible and miscellaneous”



“**Figure. 7** Response surface plot showing the effects on landfill (MT) of solid wastes for different variables of degradable, combustible and miscellaneous”