

# Response Surface Methodology to Assess an Ecofriendly Approach for Utilization of Berhampur City Municipal Solid Waste

Ladu Kishor Bisoyi, Ranjita Swain and R Bhima Rao

*Abstract --- 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). MSW management is a complex issue due to changing lifestyle of people, rapid urbanization, and under-estimated contributors and stakeholders. Disposal of solid waste is a growing environmental problem. 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 rural area developed slowly in to an urban city Berhampur, Odisha India. The study reveals that Berhampur city has 3.66 lakhs of population which generates 180 MT municipal solid wastes as per the data upto 2011 year. This city is currently recycles 12% of household waste and landfills 45% and the remaining 43% is biodegradable. The ensured optimum conditions for recycle response for solid wastes available will be 40 MT degradable, optimum combustible (MT): 9.5 and optimum miscellaneous (MT): 15.5. Similarly the optimum conditions for biodegradable response using the variables are 70 MT degradable, 17.10 MT combustible and 16.35 MT miscellaneous, whereas the optimum conditions are 70 MT degradable, 17.10 MT combustible and 17.59 MT miscellaneous for getting landfill response. This software can be applied efficiently to model the treatment of solid wastes; the method is economical and provides the maximum amount of information in a short period of time and with the smallest number of experiments. Energy can be generated and utilized for different purposes by processing the non-recyclable solid wastes. The recyclable solid wastes can be reutilized for different purpose in other small industries which helps the human civilization for better health and wealth.*

**Keywords:** Berhampur, Box-Behnken design, Odisha, Optimization, Response Surface Methodology, Solid wastes

## I. INTRODUCTION

Urbanization directly contributes to waste generation, and unscientific waste handling causes health hazards and urban environment degradation. Municipal Solid Waste (MSW) is defined to include refuse from the households, non-hazardous solid waste, discarded by the industrial, commercial and institutional establishments, market waste, yard waste and street sweepings which are collected by the municipal authorities for disposal. MSW is only a relatively small fraction of all the solid waste that is generated in an advanced economy. Municipal Solid Waste Management broadly deals with post-consumer waste, in prevention, treatment, recycle, reuse and disposal.

Some of the adverse environmental impacts of unscientific handling and indiscriminate dumping of the solid waste are: Brahmapur, nicknamed "The Silk City", is a city located in the eastern coastline of Ganjam district of the Indian state of Odisha, about 160 kilometers south of the state capital, Bhubaneswar. It is one of the oldest and the largest city of Odisha. Puri is a fastest growing tourist destination of India. A biocompost 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. At present eighty four per cent of the solid waste of the city is generated from residential areas including 110 slums where thirty per cent of the city's populace lives. The quantum of waste is being generated today is 138 TPD and is expected to increase to 250 TPD in the next three decades [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]. It describes 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 anaerobic digestion are also available

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. At present in many large cities developed countries less than 70% of MSW are collected and 50% of households are served [7]. 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. 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  $\text{CH}_4$  and 22.0 Gg of  $\text{CO}_2$ .

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, Berhampur with population 3,66,000 (2011) Eastern side is famous for the business city of Southern Odisha 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.

**II. MATERIALS AND METHODS**

The municipal solid wastes were collected from the different locations of Berhampur 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 municipal solid wastes is achieved using quadratic programming of the mathematical software package MATLAB 7.

**A. 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. The design procedure of RSM is based on the following

- Designing of experiments for adequate and reliable measurement of the response.
- Developing a mathematical model of the second – order response surface with the best fitting.
- Finding the optimal set of parameters that produce a maximum or minimum value of response.
- 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:

$$y = f(x_1, x_2, x_3, \dots, x_k) \text{ ----- (1)}$$

Where y is the output and x<sub>i</sub> 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:

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

where x<sub>1</sub>, x<sub>2</sub>, ..., x<sub>k</sub> are input factors which influence the response y; β<sub>0</sub>, β<sub>ii</sub> (i=1, 2, ..., k), β<sub>ij</sub> (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 **Y = bX + ε** ----- (3)

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

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

Table 1. List of variables at different levels

Si. No.	Variables	Low (-1)	Levels	
			Center (0)	High (+1)
1	Degradable, MT (x <sub>1</sub> )	40.00	56.00	72.00
2	Combustible, MT (x <sub>2</sub> )	9.50	19.48	17.10
3	Miscellaneous, MT (x <sub>3</sub> )	15.50	23.45	27.90

Where X' is the transpose of the matrix X and (X'.X)<sup>-1</sup> is the inverse of the matrix X'.X.

The coefficients, i.e. the main effect (b<sub>i</sub>) and two factors interactions (b<sub>ij</sub>) can be estimated from the experimental results by computer simulation programming applying the least squares method using MATLAB 7.1.

**B. 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 utilization) 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) miscellaneous by x<sub>1</sub>, x<sub>2</sub> and x<sub>3</sub> 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<sup>2</sup>+ k + c<sub>p</sub>, where k is the factor number and c<sub>p</sub> 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<sup>2</sup> factorial designs and a central point. 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:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{33} x_3^2 + \beta_{12} x_1 x_2 + \beta_{13} x_1 x_3 + \beta_{23} x_2 x_3$$

----- (5)

**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	Biodegradable, MT	Landfill, MT
		Actual	Coded	Actual	Coded	Actual	Coded			
17	1	56	0	13.3	0	21.7	0	16.8	60.2	63
7	2	40	-1	13.3	0	27.9	1	12.96	46.44	48.6
4	3	72	1	17.1	1	21.7	0	21.6	77.4	81
10	4	56	0	17.1	1	15.5	-1	12.54	20.96	15.84
9	5	56	0	9.5	-1	15.5	-1	14.88	53.32	55.8
16	6	56	0	13.3	0	21.7	0	14.88	53.32	55.8
14	7	56	0	13.3	0	21.7	0	14.88	53.32	55.8
13	8	56	0	13.3	0	21.7	0	14.88	53.32	55.8
5	9	40	-1	13.3	0	15.5	-1	12	43	45
11	10	56	0	9.5	-1	27.9	1	15.84	56.76	59.4
3	11	40	-1	17.1	1	21.7	0	17.76	60.64	66.6
12	12	56	0	17.1	1	27.9	1	18.72	65.08	70.2
2	13	72	1	9.5	-1	21.7	0	20.64	73.96	77.4
1	14	40	-1	9.5	-1	21.7	0	12	60.2	63
15	15	56	0	13.3	0	21.7	0	21.6	77.4	81
8	16	72	1	13.3	0	27.9	1	15.84	56.76	59.4
6	17	72	1	13.3	0	15.5	-1	13.92	49.88	52.2

management for 2001 to 2011 years are shown in Table. 4.

where  $y$  is the predicted response,  $\beta_0$  is a model constant;  $x_1$ ,  $x_2$  and  $x_3$  are independent variables;  $\beta_1$ ,  $\beta_2$  and  $\beta_3$  are linear coefficients;  $\beta_{12}$ ,  $\beta_{23}$  and  $\beta_{13}$  are cross product coefficients; and  $\beta_{11}$ ,  $\beta_{22}$  and  $\beta_{33}$  are the quadratic coefficients. The coefficients, i.e. the main effect ( $\beta_i$ ) and the two factor interactions ( $\beta_{ij}$ ), were estimated from the experimental results by computer-simulation programming applying the least square method using MATLAB 7.1.

### III. RESULTS AND DISCUSSIONS

#### A. Waste Management in Berhampur

Table 3 presents the status of municipal waste management in Berhampur in different years. Over 100 MT to 180 MT of waste was generated in Berhampur city, of which more than 60% was degradable waste. The amount of metals is 1.5 MT to 2.7 MT, plastic is of 5.5 MT to 9.5 MT waste and textile is generated of 5.0 MT to 9.0 MT. Paper is generated around 4.5 MT to 8.1 MT, whereas 2.0 MT to 3.6 MT glass is generated. Other wastes are varying from 41.5 MT to 74.7 MT. It is observed from Table 4 that 12.0% (12 Mt to 21.6 MT) of solid waste is currently being recycled, 43.0% (43.0 MT to 77.4 MT) is biodegradable, and 45.0% (45.0 MT to 81.0 MT) is land filled. The response from the solid waste

#### B. 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 miscellaneous (MT) of the solid wastes.

**Table 3. Waste management of Berhampur city for different year**

Year	Degradable, MT	Metals, MT	Plastic, MT	Textile, MT	Paper, MT	Glass, MT	Incombustible, MT	Miscellaneous, MT
2001	40	1.5	5.5	5	4.5	2	35	6.5
2002	43.2	1.62	5.94	5.4	4.86	2.16	37.8	7.02
2003	46.4	1.74	6.38	5.8	5.22	2.32	40.6	7.54
2004	49.6	1.86	6.82	6.2	5.49	2.48	43.4	8.06
2005	52.8	1.98	7.76	6.6	5.94	2.64	46.2	8.58
2006	56	2.1	7.7	7	6.3	2.8	49	9.1
2007	59.2	2.22	8.14	7.4	6.66	2.96	51.8	9.62
2008	62.4	2.34	8.58	7.8	7.02	3.12	54.6	10.14
2009	65.6	2.46	9.02	8.2	7.38	3.28	57.4	10.66
2010	68.8	2.58	9.46	8.6	7.74	3.44	60.2	11.18
2011	72	2.7	9.9	9	8.1	3.6	63	11.7

**Table 4 Responses of waste generated of Berhampur city for different years**

Year	Recyclable, MT	Biodegradable, MT	Landfill, MT	Recyclable, %	Biodegradable, %	Landfill, %
2001	12	43	45	12	43	45
2002	12.96	46.44	48.6	12	43	45
2003	13.92	49.88	52.2	12	43	45
2004	14.88	53.32	55.8	12	43	45
2005	15.84	56.76	59.4	12	43	45
2006	16.8	60.2	63	12	43	45
2007	17.76	63.64	66.6	12	43	45
2008	18.72	67.08	70.2	12	43	45
2009	19.68	70.52	73.8	12	43	45
2010	20.64	73.96	77.4	12	43	45
2011	21.6	77.4	81	12	43	45

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

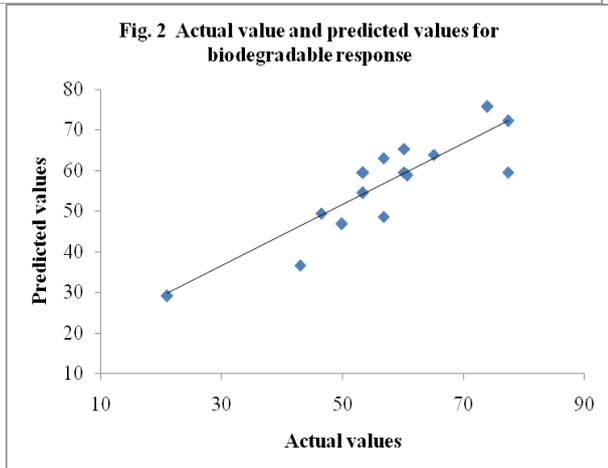
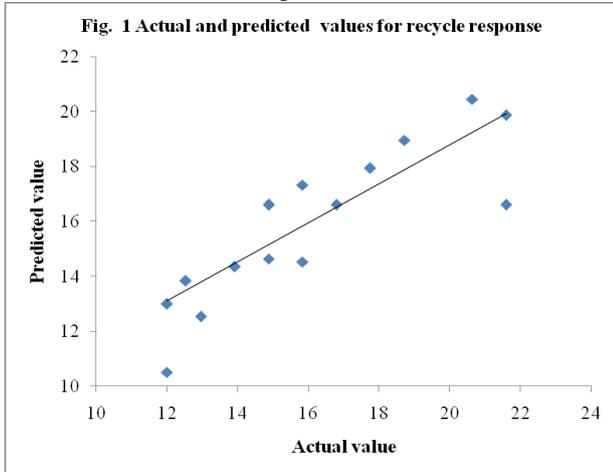
Standard Order	Recycle		Biodegradable		Landfill	
	Actual Value	Predicted Value	Actual Value	Predicted Value	Actual Value	Predicted Value
1	12.0	13.7	60.2	65.4	63.0	68.9
2	20.6	20.5	74.0	75.8	77.4	80.6
3	17.8	17.9	60.6	58.8	66.6	63.4
4	21.6	19.9	77.4	72.2	81.0	75.1
5	12.0	10.5	43.0	36.7	45.0	37.8
6	13.9	14.3	49.9	46.9	52.2	47.7
7	13.0	12.5	46.4	49.4	48.6	53.1
8	15.8	17.3	56.8	63.1	59.4	66.6
9	14.9	14.6	53.3	54.5	55.8	57.2
10	12.5	13.8	21.0	29.1	15.8	26.3
11	15.8	14.5	56.8	48.6	59.4	49.0
12	18.7	19.0	65.1	63.9	70.2	68.9
13	14.9	16.6	53.3	59.5	55.8	62.3
14	14.9	16.6	53.3	59.5	55.8	62.3
15	21.6	16.6	77.4	59.5	81.0	62.3
16	14.9	16.6	53.3	59.5	55.8	62.3
17	16.8	16.6	60.2	59.5	63.0	62.3

The relationship between response and variables was obtained for coded unit as follows: treatment of solid waste for recycle process:

$$y_1 = +16.61 + 2.16 * x_1 + 0.91 * x_2 + 1.25 * x_3 - 0.21 * x_1^2 + 1.60 * x_2^2 - 2.72 * x_3^2 - 1.20 * x_1 * x_2 + 0.24 * x_2 * x_3 + 1.31 * x_1 * x_3 \text{ ----- (6)}$$

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 5 and shown in Figure 1. The predicted values and the observed data points, was indicating a average fit (R<sup>2</sup> value of 0.71 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:  $y_2 = +59.21 + 5.97 * x_1 - 2.52 * x_2 + 7.23 * x_3 + 4.26 * x_1^2 + 4.27 * x_2^2 - 14.76 * x_3^2 + 0.75 * x_1 * x_2 + 0.86 * x_1 * x_3 + 10.17 * x_2 * x_3 \text{ -- --(7)}$

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 5 and shown in Figure 2. The predicted values and the observed data points are indicating a average fit (R<sup>2</sup> value of 0.75 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:

$$y_3 = +62.28 + 5.85 * x_1 - 2.74 * x_2 + 8.60 * x_3 + 5.36 * x_1^2 + 4.36 * x_2^2 - 16.33 * x_3^2 - 0.0 * x_1 * x_2 + 0.90 * x_1 * x_3 + 12.69 * x_2 * x_3 \text{ ---- (8)}$$

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 3. The predicted values and the observed data points are indicating a average fit (R<sup>2</sup> value of 0.75) for solid wastes utilized as land fill for the response equation.

**C. Optimization of variables of recycle**

One of the main aims of this study was to maximize the recycle of the solid wastes of Berhampur, 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). The operation variables for recycle of the solid wastes as determined are:

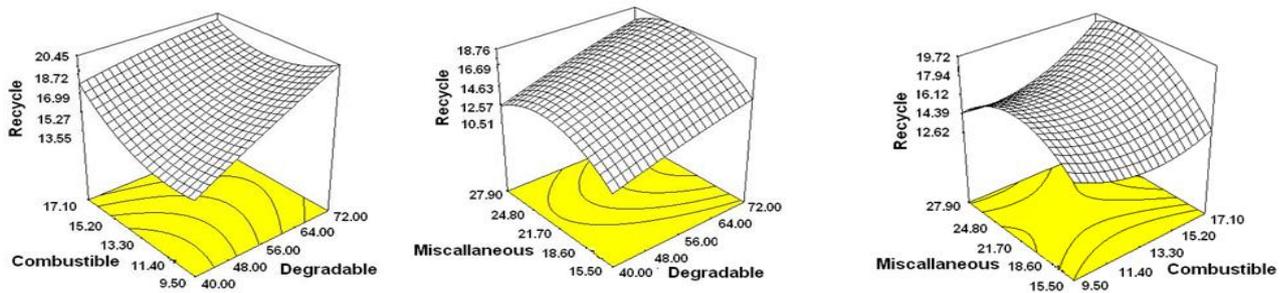
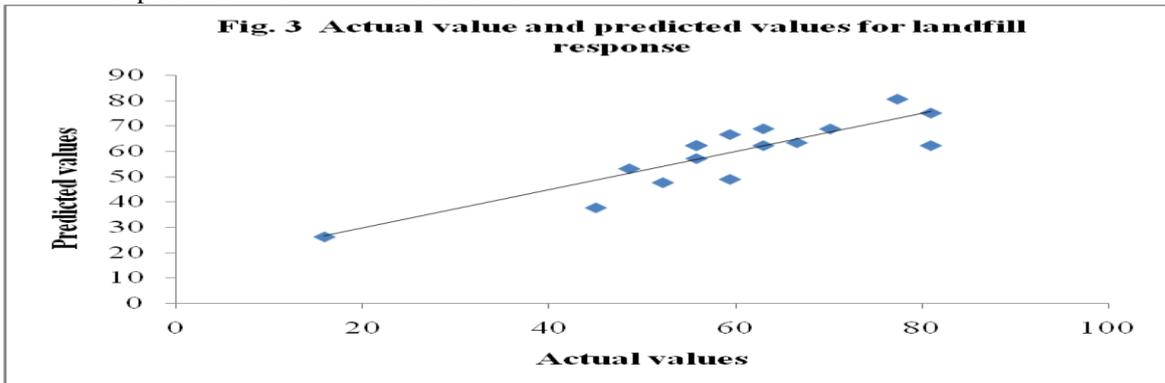
- Optimum concentration of degradable (MT): 40.00, Optimum combustible (MT): 9.50
- Optimum Miscellaneous (MT): 15.50
- The operation variables used as biodegradable of the solid wastes as determined are:
- Optimum concentration of degradable (MT): 72.0, Optimum combustible (MT): 17.10, Optimum Miscellaneous (MT): 16.35
- The operation variables for the solid wastes utilized as landfill determined are:
- Optimum concentration of degradable (MT): 72.00 Optimum combustible (MT): 17.10, Optimum Miscellaneous (MT): 17.59

In order to gain a better understanding of the results, the predicted models were presented in Figures. 4-6 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.

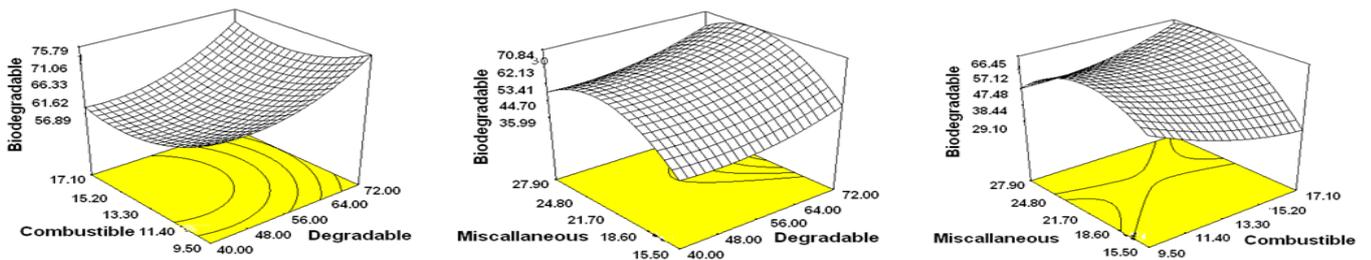
**IV. CONCLUSION**

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

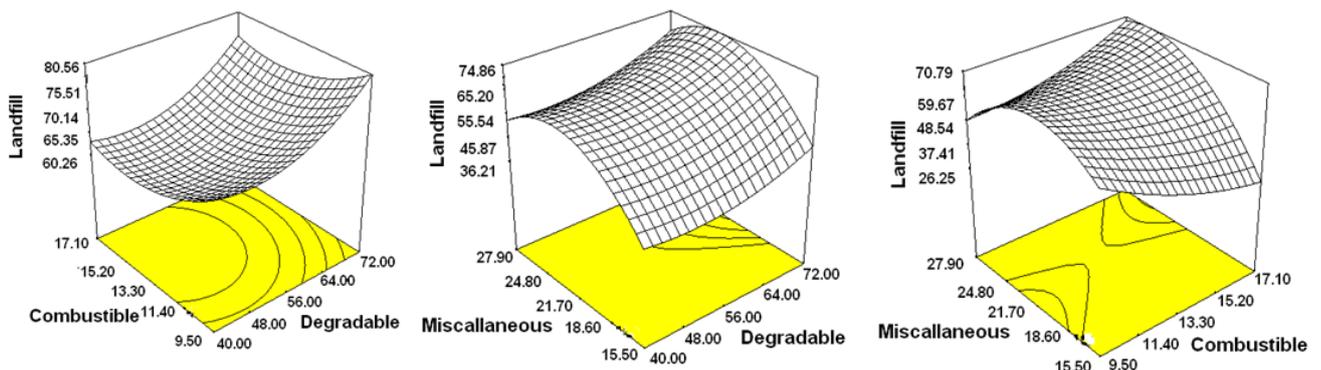
responses show good agreement. The solid wastes can be reutilized after processing for different purposes. The process helps to protect from environmental pollution. Energy can be utilized for different purposes by processing the non-recyclable solid wastes. It also helps the human civilization for better health and wealth.



**Fig.4** Response surface plot showing the effects on recycle (MT) of solid wastes for different variables of degradable, combustible and miscellaneous



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



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

REFERENCES

- [1] City Managers Association Orissa, Documentation on Bio Composting-solid waste management of Puri, 2009.
- [2] <http://www.orissadiary.com/Berhampur/ShowCityNews.asp?id=41388#sthash.KtSYoJ7Y.dpuf>. Retrieved in 2013.
- [3] C. Gallis<sup>1</sup>, K. Giagli, V. Karypidoy, "Report on Quantitative and Geographical Analysis of Solid Waste Landfill Data in the Municipalities Union of Thessaloniki Greater Area for the Period 2004 – 2008", In *HazWasManagement*, 2010, pp-31.
- [4] Zhu Minghua, Fan Xiumin, Alberto Rovetta, He Qichang, Federico Vicentini, Liu Bingkai, Alessandro Giusti, Liu Yi, "Municipal solid waste management in Pudong New Area, China", *Waste Management*, 2009, 29, pp. 227–1233.
- [5] Ryu, Changkook., "Potential of municipal solid waste for renewable energy production and reduction of greenhouse gas emissions in South Korea", *Journal of the Air & Waste Management Association*, Vol.60, 2010, pp. 176-184.
- [6] Ming-Chien Hung, Shu-Kuang Ning\*, Ya-Hsuan Chou, "Environmental Impact Evaluation for Various Incinerator Patterns by Life Cycle Perspective: A Case Study in Taiwan", 2nd International Conference on Environmental Science and Technology, IPCBEE, IACSIT Press, Singapore, vol.6, 2011, pp. VI 84-VI 86.
- [7] L. K. Bisoyi, "Solid Waste Management in Puri Municipality, Orissa Review", Institute of the Co-operative Management, 2005, p 91-95, Retrieved in 2013.
- [8] P.S Bundela, S.P. Gautam, A.K. Pandey, M.K. Awasthi, S. Sarsaiya, "Municipal solid waste management in Indian cities – A review", *International Journal of Environmental Sciences*, Volume 1, No 4, 2010.
- [9] Yi Xiao, Xuemei Bai, Zhiyun Ouyang, Hua Zheng and Fangfang Xing, "The composition, trend and impact of urban solid waste in Beijing", *Environ Monit Assess*, 2006.
- [10] A.S. Souzaa, W.N.L dos Santos and L.C. Sergio Ferreira, "Application of Box\_Behnken design in the optimization of an on-line pre-concentration system using knotted reactor for cadmium determination by flame atomic absorption spectrometry", *Spectrochimica Acta Part B*, 60, 2005, pp. 737-742.
- [11] N.Aslan, and Y.Cebeci., "Application of Box Behnken design and response surface methodology for modeling of some Turkish coals.", *Fuel*, Vol. 86, 2007, 90-97.
- [12] G.E.P. Box and D.W. Behnken., "Some new three level designs for the study of quantitative variables", *Technometrics*, Vol. 2, 1960, pp. 455-475.
- [13] G.E.P. Box, and Wilson, K.B, "On the experimental attainment of optimum conditions", *Journal of the Royal Statistical Society*, B13, 1951, pp. 1-45.
- [14] G.E.P Box, W.G. Hunter and J.S. Hunter, "Statistics for Experimenters: an Introduction to Design", *Data Analysis and Model Building*, John Wiley and Sons, New York, 1978, p. 653.
- [15] S.L.C. Ferreira, W.N.L. Dos Santos, C. M. Quintella, B. B. Neto and J.M. Boque-Sendra, "Doehlert matrix: a chemometric toll for analytical chemistry – review", *Talanta*. Vol. 63, 2004, 1061-1067.
- [16] D. C. Montgomery, "Design and Analysis of Experiments", 5th edition. John Wiley & Sons, New York, 2001, pp. 684.
- [17] J. S. Kwak, "Application of Taguchi and response surface methodologies for geometric error in surface grinding process", *International Journal of Machine Tools and Manufacture.*, Vol. 45,2005, pp. 327-334.
- [18] V. Gunaraj and N. Murugan., "Application of response surface methodologies for predicting weld base quality in submerged arc welding of pipes", *Journal of Materials Processing Technology*, Vol. 88, 1999, pp. 266-275.
- [19] N. Aslan, "Modeling and optimization of Multi- Gravity Separator to produce Celestine concentrate", *Powder Technology*, Vol. 174, 2007b, pp. 127-133.
- [20] N. Aslan, F. Cifcia and D. Yanb., Optimization of process parameters for producing graphite concentrate using response surface methodology, *Separation and Purification Technology*, Vol. 59, 2008, pp. 9–16.
- [21] Nevzat. Aslan, "Multi-objective optimization of some process parameters of a multi-gravity separator for chromite concentration", *Separation and Purification Technology*, Vol. 64, 2008, pp. 237-241.
- [22] Ozgen, Selcuk and Ahmet, Yildiz, "Application of Box–Behnken design to modeling the effect of smectite content on swelling to hydro cyclone processing of bentonites with various geologic properties", *Clays and Clay Minerals*, Vol. 58(3), 2010, pp. 431- 448.
- [23] Sunil. Kumar. Tripathy, Y. Ramamuthy and C. Raghu. Kumar, Modeling of high-tension roll separator for separation of titanium bearing minerals", *Powder Technology*, Vol. 201, 2010, pp. 181-186.
- [24] Massart, D.L., Vandeginste, B.G.M., Buydens, L.M.C., Jong, S., Lewi, P.J., and Smeyers Verbeke, J., 1997. *Handbook of Chemo metrics and Qualimetrics Part A*. Elsevier Publishing Company, Amsterdam, pp.886.
- [25] B. B. Neto, I. S. Scarminio and R.E. Bruns., "Como fazer Experimentos: Pesquisae Desenvolvimento na Cie`ncia e na Industria. Editor a da Unicamp", Sa`o Paulo, 2001, p. 480.
- [26] Gaurav. Mohanty, Laxmidhar. Besra, Sarama. Bhattacharjee and Bimal. P. Singh., "Optimization of electrophoretic deposition of alumina onto steel substrates from its suspension in iso-propanol using statistical design of experiments," *Materials Research Bulletin*, Vol. 43, 2008, pp. 1814–1828.



Er.(Dr.) L.K. Bisoyi working as Senior Consultant & advisor group (SCAG) Bhubaneswar, Associated with social services and Principal SMIT Degree Engineering College, Berhampur, Ganjam, Orissa since 2009. Er.(Dr.) L.K. Bisoyi, FIE (India), ME (PH), FI PHE (India), Former Executive Engineer, H & UD Dept. Government of Orissa. Master in Engineering in Public Health from Kolkata University 1992-93 Special Refresher Course. (6 weeks) in Geo-Physics from National Geo-Physical Research Institute, Hyderabad, Ph.D. in Environment Science & Engineering on "Solid Waste Management at Mining Site" from International University, Washington DC, USA - 2008. Published 223 nos of technical articles in National and International level, on Research and Development in Public Health and Environment. 14 Gold Medals, 10 Cash Awards in State level and nos of mementos. Felicitation by District Administration Sundargarh District Orissa by National day organization committee Rourkela Orissa on 26 January 2003 at Rourkela and by I.E (India) in Berhampur local center as senior Engineer during 2006. "Eminent Environment Engineer" National Award by Environment Engineering Division Institution of Engineers (India) at Tiruchirapalli local centre in November 2005. Vijaya Shree and Glory of India Award by an International NGO (New Delhi based). Received no of mementos in token of presentation of technical Hony. Secretary (IE) India, Orissa State Center (2006-2008), Chairman (IE) India, Orissa State Center (2008-2010), Chairman (ENDB) IE (India) (2008-2010), Presently: Principal, Degree Engineer College, Berhampur, Orissa since 2009 & Continuing, Committee member ENDB IE (India) (2011), Committee member ENDB IE (India) Odisha State Center Bhubaneswar, 2004-2006, 2006-2008, 2008-2010, 2010-2012, & 2012-2014.



Dr. Ranjita Swain, Asst. Prof., CV Raman College of Engineering, Bhubaneswar, Odisha, India after completed Ph. D from SOA University, Bhubaneswar India. She is a graduate in Chemical Engineering from Berhampur University, India, joined as Senior Research Fellow in CSIR- Institute of Minerals and Materials Technology, Bhubaneswar, India. To her credit she has published twenty research papers in National and International journals as well as in seminar proceedings. She won best paper awards by the Institution of Engineers, Odisha State Center, India. She has gained in depth knowledge and experience in the area of Mineral Processing.



Dr. R. Bhima Rao born in the year 1952 is at present working as a Principal in AIET, Bhubaneswar, Odisha, India. He was being a Chief scientist in Institute of Minerals and Materials Technology (CSIR0, Govt. of India, Bhubaneswar after completing his double post graduation from college of Science and Technology and college of Engineering, Andhra University, Visakhapatnam. Dr. Rao has obtained doctorate degree in Mineral Engineering from Indian School of Mines, Dhanbad. He has visited Lulea University of Technology, Lulea, Sweden as a Guest Researcher. He has gained in-depth knowledge and experience in the fields of characterization, liberation of values/gangue from the ore, fine particle processing, selection, scaling up and operational problems of comminution circuits, gravity concentration, magnetic separation, flotation, auditing/ modification and process flow sheet developments for various ores, mineral and metallurgical wastes from different operating Indian mineral processing industries. Due to his exemplary work on beneficiation, a few beneficiation plants have been set up in India. He has received many best paper awards and recognitions especially in the area of additives in grinding. The National Mineral Award in the area of mineral beneficiation (instituted under the National Mineral Award Scheme of Ministry of Mines) is one of his prestigious recognitions.