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Optimizing the exhaust emission from logistics and packing industries, by means of green logistics

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Abstract. The product packing, is an essential process for preserving the product but it also emits higher percentages of green house gases to the atmosphere, while decomposing it. Therefore, it leads to a new science named 'Green packing', which deals with the process of identifying Eco-compatible materials for packing. This article aims at detecting: the high performing packing factor for green house gas emission and also to develop an optimized values for packing enterprises to mitigate the emission. The results achieved shows that packing material selection has a huge influence on green house gas emission.

Keywords: Green house gas emission, Taguchi method, green logistics.

1. Introduction

Green logistics is defined as an initiative to control the [1] harm made to the environment by logistics by using cutting edge tools. It can be strategically executed by the tactical planning of merging the tri-poles namely: economic field, social field and environmental field of an industry. A survey made on 2009, reveals that china's manufacturing goods overwhelms the competitive nations, but it drives them to deplete and exploit the available natural resources. This leads the policy makers to introduce a jargon named 'Circular Economy,' which connects the business demand of each product with the shortage of resources, through an interface called Green logistics management [2] [3]. There after it is renamed as "environmental logistics" by the china's national standard organization [4]. Moreover, logistics companies from european union countries have established a standard interface between customers and manufacturers; to facilitate the dialogue in the domains of electronic wastes recycling, eco-friendly packing, vehicle clinic centers for reducing pollution [6].



Environmental regulations, are also an useful motivating tool for implementing green logistics management. Some of the Eco-policies in the developed nations are: discouraging the unprocessed waste disposal by heavy taxes, incentives are added along with every purchase of nature-friendly raw material, tax subsidies for every environment-friendly product [7]. The aim of this article, is to identify the high ranking parameter of an packed product, which can trigger the green house gas emission and also to determine the optimized settings of packing parameters, to mitigate the green house gas emission.

2. Literature Review:

In many developing countries, environmental pollution policies are introduced in multiple domains, since 1990. Moreover, it is observed that obsolete monitoring equipment in use, reduces the pace of green practices and therefore the governing committee exhorts the enterprises to use RFID's, electronic logistic information technology such as: bar code, magnetic card and so on[8] [9]. Along with that, few functional non-green parameters in the logistics domain are detected. Based on that countermeasures, are evolved to reduce: pollution emission and fresh resource intake as raw materials [10].

Based on the evidence, it is inferred that eco-friendly policy is a seed for any environmental initiatives. To nurture a green logistics field, from a sapling stage to a deep-rooted tree; few critical goals are to be pursued, and they are given below [11], [12];

- ✧ To develop a new green logistics theory, along with empirically proven policies.
- ✧ To revamp the operating mode of an existing practices in preferred enterprises.
- ✧ To develop a clean fuel.
- ✧ To optimize a distribution route.
- ✧ To utilize the transport efficiently.
- ✧ To reduce the delivery error.
- ✧ To promote the green storage and green packaging.
- ✧ To protect the urban environment.
- ✧ To organize the disorderly competition, exists between the primary logistics players.

3. Green House Gas Emission From Packing

Most of the non-green packing materials (such as white plastics) comprises of: polyvinyl chloride, a resource for green house gases (CO₂, N₂O, CH₄). The other alternative of non -green packaging are: mushroom packaging (MP), carbon positive packaging (CPP) and cardboard packaging.

Carbon positive packaging is a byproduct, while sugar manufacturing. It has a function ability to absorb carbon dioxide and emits oxygen to atmosphere. Cardboard packaging is made by chlorine chemical structure, and it is also an environmentally digestive product [13].

4. Methodology

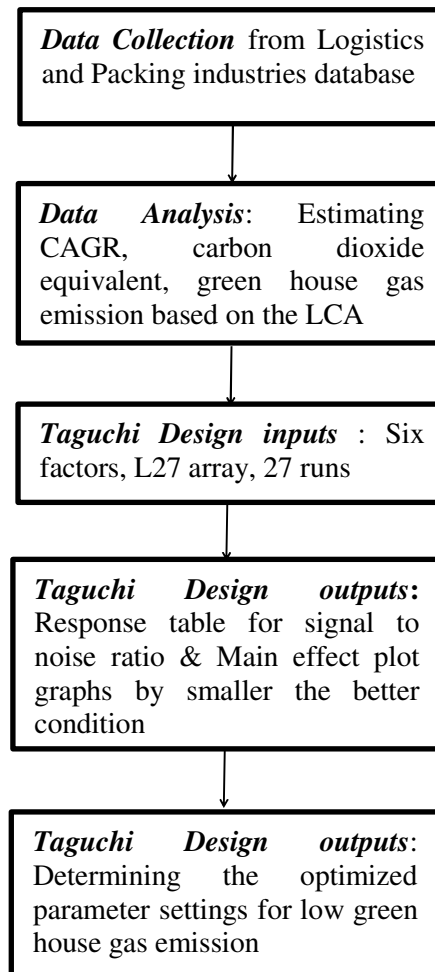


Figure-1: Methodology Of Problem

The above methodology chart (Fig-1), depicts the progression of the problem. The initial step is data collection from packing industries, followed by data analysis using Taguchi method. L27 array is selected for analysis with six parameters and two levels.

5. Green Packing

Green packing is defined as the process of providing essential layers to a product with bio-degradable simple layers to improve recyclable nature and quick disposal of materials. White plastic utility usage [14], have to be avoided due to non-degradable nature .

5.1 Principles of green packaging (4R+1D):

- Reduce (R1) : Design of green packaging should be thin and light weight.
- Reuse (R2): By basic and simple treatment, utilized containers can be further used for multiple times.
- Reclaim/Reusable (R3): Accumulation of waste materials for combustion should produce green energy rather than harmful gasses.

- Recycle (R4): A partial quantity of reusable raw materials have to extracted from the used materials, and re-induced in the production, rather than using fresh raw materials on every time.
- Degradable (D): Recyclable packing waste should have an ability for easy degrading, after it is utilized for several times.[15]

5.2 Strategies for green packing:

5.2.1 Federal Level:

- Regulations for green packing have to be formulated, with an intent of environmental purification.
- Design and development of dedicated green storage cells for daily consuming liquids like water, beer et al; are required.
- Biodegradable empty cans could be collected back by the retail outlets, with an incentive of cash back offers and discount coupons.
- Promotion of new green packing material through online media, daily newspapers, and hoarding boards have to be done.

5.2.2 Firm Level:

- The symbols and signs have to be printed on the green packing box.
- Green packet design have to done based on an intent of disassembly and recycling.
- A green packing material preference is based on following parameters namely: customer's green demands; light weight; thin fluorine-free and high-performance materials.

5.2.3 Adverse impacts of Non green packing:

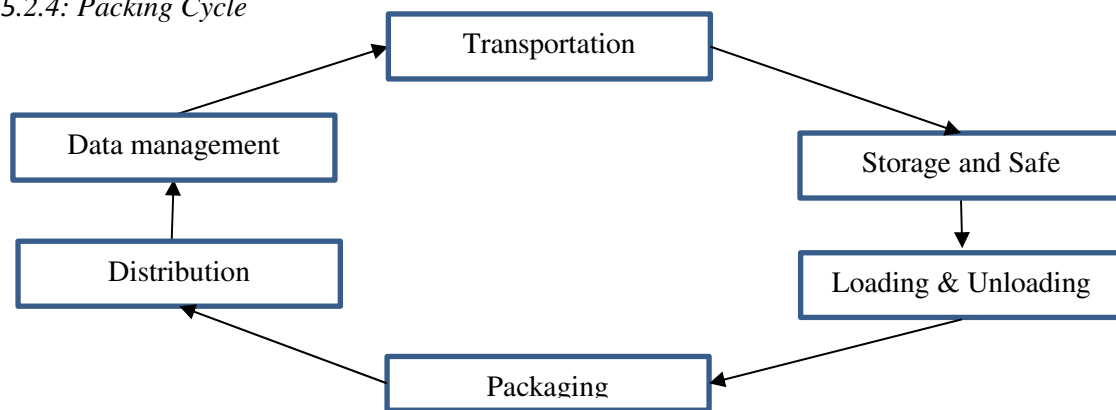
Solid waste:

* The total gross of solid waste generated annually are approximately ten million tons in the world; besides one-third of its waste are generated from packing. Some of the packing waste materials are paper, white plastic, metal, glass and other ingredients.

Bacteria and pest spreading:

* The crop pest and various bacteria packed in the less protected packing will be a potential for an emerging damage to the safety stock and humans.

5.2.4: Packing Cycle

**Figure-2:** Cycle of Packing

The above flow chart depicts the packing cycle (Fig-2) involved in the logistics. In the early 19th century, logistics term is defined only for the activities namely: inbound and outbound transportation. But in the later half, the logistics scope is extended to multiple domains namely: Warehousing, automated loading and unloading, packing, distribution and data management. This article focused on packing domain of logistics.

5.2.6: Terminologies used in greenhouse gas emission calculation,

(i) Compound annual growth rate (CAGR)

Compound annual growth rate is a relative term, used to calculate the annual progression (revenue/sales) between two different time frames, of an firm. It is defined as the ratio of recent years revenue to the last year revenue.

$$[\text{CAGR}]_{2003}^{2015} = \left[\left\{ \frac{(\text{Revenue during 2015 year})}{(\text{Revenue duing 2003 year})} \right\}^{(1/12)} - 1 \right] \times 100$$

(ii) Carbon dioxide equivalent (CO₂e)

Carbon dioxide equivalent (CO₂e) is defined as a product of green house gas acquired from the process and the global warming potential. (Note: Global warming potential is an constant term assigned for measuring the potential of green house gas. Eg. GWP for carbon dioxide is one ; GWP for methane is 25; GWP foras Nitrogen dioxide is 298.)

$$(\text{CO}_2\text{e})^{\text{gas}_1} = \left\{ \left\{ \text{Total green house gas (CO}_2/\text{CH}_4/\text{N}_2\text{O)} \text{ acquired from the process} \right\} \times \left\{ \text{GWP (global warming potential for CO}_2/\text{CH}_4/\text{N}_2\text{O)} \right\} \right\}$$

6. Data Analysis

6.1: Taguchi Method

The steps involved in Taguchi Method are

- Data collected are arranged systematically, and then outcome variable and control parameters are calculated from the available data.
- Taguchi design done, by identifying the optimum orthogonal array for the given inputs.
- The levels of each factors are found out, based on the available data.
- Experimental results are analyzed and based on the result, and then the optimized values for each factor was recognized..
- The obtained results are then compared with the experimental values.

In Taguchi method, the L27 (6 X 3) orthogonal array is selected for analysis. The inputs given are: six factors; three levels, 27 iterations; whereas ‘Smaller the better’ condition is selected for the ranking method. Entire lot, of Taguchi calculation (Table-6) is done by Minitab software tool.

6.2: Taguchi Design:

The input parameters required for processing taguchi method are organized under three levels namely: Level-1, 2, 3. The parameters identified are equivalent to six and they are arranged in a tabular form.

TABLE-1: Selected Input Parameters at Three Levels

SNO	CONTROLLED FACTORS	LEVEL-1	LEVEL-2	LEVEL-3
1.	A : Revenue attained in packing industries for an year 2015 (Million Dollars)	52	171	287
2.	B: Packing units Sold (Billion)	127	1494	2861
3.	C: Compound annual growth rate (2015)	0.77	16	30.34
4.	D:Materials used for packing	1.5	2.5	3.5
5.	E: Quantity consumed in Kilo tons	5581	43666	81750
6.	F: Carbon dioxide equivalent of Packing materials	1	1.23E7	2.46E7

The levels of a factor (Table-1) is defined as multi range of (finite) values, which can trigger the response of an experiment (Fuel consumption).

Taguchi design (Table-2) will provide a optimized proposition for all six parameters, in-order to achieve the minimum outcome (i.e., smaller the better for green house gas emission).Table-3 is also utilized as a reference table for detecting the optimum values, furnished by six key parameters.

TABLE-2: L27 Design Array of the experiment

SNO	A	B	C	D	E	F
1	52	127	0.77	1.5	5581	1
2	52	127	0.77	1.5	43666	1.23E+07
3	52	127	0.77	1.5	81750	2.46E+07
4	52	1494	16	2.5	5581	1
5	52	1494	16	2.5	43666	1.23E+07
6	52	1494	16	2.5	81750	2.46E+07
7	52	2861	30.34	3.5	5581	1

SNO	A	B	C	D	E	F
8	52	2861	30.34	3.5	43666	1.23E+07
9	52	2861	30.34	3.5	81750	2.46E+07
10	171	127	16	3.5	5581	1.23E+07
11	171	127	16	3.5	43666	2.46E+07
12	171	127	16	3.5	81750	1
13	171	1494	30.34	1.5	5581	1.23E+07
14	171	1494	30.34	1.5	43666	2.46E+07
15	171	1494	30.34	1.5	81750	1
16	171	2861	0.77	2.5	5581	1.23E+07
17	171	2861	0.77	2.5	43666	2.46E+07
18	171	2861	0.77	2.5	81750	1
19	287	127	30.34	2.5	5581	2.46E+07
20	287	127	30.34	2.5	43666	1
21	287	127	30.34	2.5	81750	1.23E+07
22	287	1494	0.77	3.5	5581	2.46E+07
23	287	1494	0.77	3.5	43666	1
24	287	1494	0.77	3.5	81750	1.23E+07

TABLE-3: S/N Ratio Formulations

SNO	S/N RATIO CONFIGURATION	FORMULAE
1.	The Smaller-The better	$S/N = -10 \log (\sum Y^2/n)$
2.	The higher-The better	$S/N = -10 \log (\sum (1/Y^2) /n)$
3.	The more nominal-the better	$S/N = -10 \log (\sum Y^2/S^2)$

The formulae for calculating the Signal to Noise ratio values are given in the Table-3. This article follows the condition Smaller the better. Hence, the formulae ($S/N = -10 \log (\sum Y^2/n)$) is used in calculating those values.

TABLE-4: Response Table for Signal to Noise Ratios (Smaller is better)

Level	Revenue in packing industry for an year (2015) -{Million dollars} (A)	Packing Units sold (Billion) (B)	CAGR-2015 (C)	Packing Materials (D)	Quantity consumed in Kilotons (E)	CO ₂ e of Packing materials (F)
1	-89.57	-99.58	-104.66	-107.42	-89.57	-87.02
2	-97.1	-73.04	-83.43	-78.98	-97.1	-126.69
3.	-98.16	-112.22	-96.74	-98.44	-98.16	-71.12
Delta	8.59	39.18	21.23	28.44	8.59	55.57
Rank	5	2	4	3	6	1

The response values for each parameter is calculated by the formula: $S/N = -10 \log (\sum Y^2/n)$ based on the condition : Smaller the better. Based on the highest scalar value of Delta, (Table-5) the ranking is done. Based on the delta ranking, parameter-F(CO₂e), B (Units sold), D (Packing materials) occupies the top three spaces respectively.

6.3 Data Outcome

This section, have captured the outcome of Taguchi model and it is organised in Table-5. Two outcomes of Taguchi model are S/N ratio (Signal to Noise ratio) and Means (Average).

TABLE-5: Experimental values for the Green House gas emission

SNO	Green house gas Emission (Kilotons)	
	S/N ratio	Means
1	-68.018	2517
2	-135.807	6170930
3	-145.349	18512790
4	0	1
5	-120.542	1064408
6	0	1
7	-147.848	24683720
8	-120.542	1064408
9	-68.018	2517
10	-135.807	6170930
11	-145.349	18512790
12	0	1
13	-120.542	1064408
14	0	1
15	-147.848	24683720
16	-120.542	1064408
17	-68.018	2517
18	-135.807	6170930
19	-145.349	18512790
20	0	1
21	-120.542	1064408
22	0	1
23	-147.848	24683720
24	-120.542	1064408
25	-68.018	2517
26	-135.807	6170930
27	-145.349	18512790

The values of the above table (Table-5) are extracted from the graph (figure-3). The graph (figure-3) was processed with the response condition: smaller the better. The inference from the graph based on the optimum levels of parameters are: A3-B3-C2-D1-E3-F2. These optimized level values, are then translated to optimized experimental values; which are also captured in the 27th iteration of Table-2 & Table-6. The experimental value attained is the smallest value of all the 27 iterations. The optimum parameters achieved (based on the principle: Smaller the better) are: A3(287) - B3(2861) -

C2(16)- D1(1.5)- E3(81750) - F2(1.23E7) value. The predicted Optimum Signal to noise ratio and experimental value are extracted from the table-7 (26th Iteration).

TABLE-6: Optimum Settings For Low Emission Of Green House Gas

SNO	CONTROLLED PARAMETERS	Green House gas Emission
1.	A : Revenue attained in packing industry for an year (Million Dollars)	287
2.	B: Packing units Sold (Billion)	2861
3.	C: Compound annual growth rate (2015)	16
4.	D:Materials used for packing	1.5
5.	E: Quantity consumed in Kilo tons	81750
6.	F: Carbon dioxide equivalent of Packing materials	1.23 X 10 ⁷
	Experimental Outcome	1.85 X 10 ⁷ Kilotons
	Signal to Noise ratio	-145.349
	Means	1.85 X 10 ⁷

7. Graphical Inferences

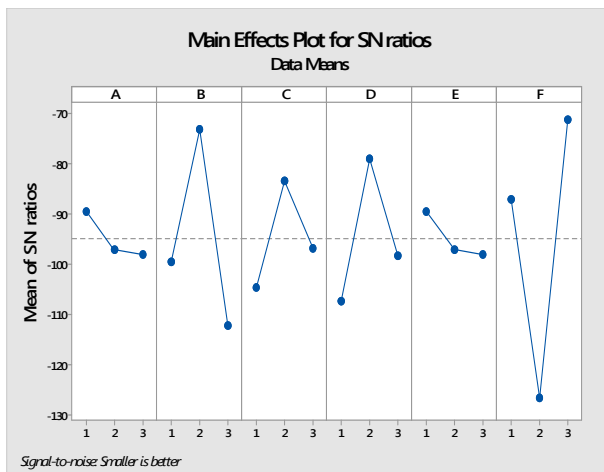


Figure-3: Main effect plot for SN ratios

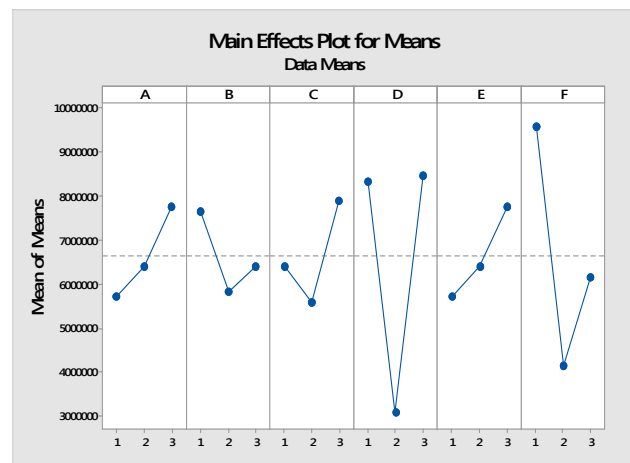


Figure-4: Main effect plot for means

Graphical figures (Fig-3 & 4) mentioned in this section, estimates the optimum settings; in-order to achieve the target of reducing the green house gas emission. Figure-3, portrays the optimized level values for SN ratios (Signal to Noise). Based on the condition of smaller the better, these level values (A3-B3-C2-D1-E3-F2) are considered as the optimum settings. Figure-4 portrays the optimized settings for the mean values. The optimized level setting of packing system for means are: A1-B2-C2-D2-E1-F2. The plot for figure-3 are considered for optimum value estimation, because of its alignment with objective function. (i.e. reducing Green house gas emission.)

8. RESULTS AND DISCUSSIONS

The list of packing parameters identified are: revenue attained in packing industry for an year; packing units sold; compound annual growth rate; materials used for packing; packing quantity consumed in kilotons; carbondioxide equivalent of materials. Based on delta values (Table-5), high ranking packing parameter are: carbondioxide equivalent of packing material; packing units sold per year and packing materials used for logistics. Packing material selection is a key packing factor as it has an dominion over carbon dioxide equivalent also. The packing materials sales trend on recent years shows that white plastics are showing a steep high whereas recyclable materials (namely carton box) are not in appreciable growth. It is necessary to conduct promotional events on green packaging for end users, during every quarter of the financial year. Logistic service providers can mitigate the green house gas emission, by adopting optimized value settings of packing parameters mentioned in the tabular column (Table-7). Based on the two results attained above (Table-5 & 7), the green house gas emission can be mitigated by two poles namely: customer's wish for green marketing and logistic service provider's packing material selection .

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