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A HOLISTIC ANALYSIS OF SUSTAINABILITY IN PLASTICS

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Abstract: Now-a-days plastic is one of the most used materials in the world. Life without the use of vast range of plastic products makes it almost unthinkable. However, due to its chemical structure and non-degradability, it has given birth to the various abhorring issues of urban pollution, marine pollution, demand for adequate waste management, and heavy recycling among others. In addition, this situation is further exacerbated by the extensive use of petro-based plastics. Nevertheless bio-based plastics seem quite promising to reduce afore-mentioned issues. Hence, it is essential to develop a methodology for a system-wide analysis, which will aid the plastic industry in understanding sustainability. To this aim, this paper develops a methodology by conducting a survey in plastic industries of Pakistan and then deploying the Analytic Hierarchic Process to compare petro-based plastics and bio-based plastics to measure their sustainability. Results reveal that bio-based plastics are more sustainable as compared to petro-based plastics.
Keywords: Analytic Hierarchy Process (AHP), Sustainability, Plastics, Bio-based plastics, Petro-based plastics.

1. Introduction

Plastics are the key component of thousands of other manufactured items and household appliances. Experts classify the plastic industry into two major classes, (i) Upstream and (ii) Downstream. The Upstream plastic industries are the ones that convert polymers extracted from petroleum to the basic chemicals such as polypropylene and polyethylene, while the downstream plastic industries are the ones that manufacture a wide variety of products used in the daily life from these polymers. There are about 6500 plastic processing industries in the industrial zones of all major cities of Pakistan [1]. The annual growth rate of plastic industry in Pakistan is 15% and its annual production is 624,200 metric tons [2]. US$ 260 billion have been so far invested in the industry which increased our plastic exports nearly 35% [3]. The industry contributes about 7.5 Billion rupees per year the country's revenue while its share in GDP is 1.69% [3]. Plastic processing industry runs with high technological machinery most of which is imported from China, Japan, Taiwan, Italy, Germany, Korea, England, and Hong Kong. However, indigenously manufactured machines are also used seldom. The plastic industry is hugely un-organized that has entirely been self-financed in last ten years despite it has been growing much faster. Plastic Resin manufacturers import the basic polymer of

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polypropylene and polyethylene for plastic resin manufacturing from different countries like USA, Malaysia, UAE, Taiwan, Singapore, and Germany [4].

The import cost of polyethylene (PE) and polypropylene (PP) was $700 Million in 2009 being 76% of the total plastic import [5]. It is estimated by World Wildlife Fund 14 billion pounds of solid waste most of which is plastics are dumped every year in oceans [6]. Harmful chemicals such as phthalates, flame retardants bisphenol A and other special additives are added while manufacturing plastics in order to achieve certain desired properties. Several experiments all over the world has confirmed these effects of regular petro-based plastics [7, 8]. With the extensive usage of plastics we should consider the disadvantages of regular petro-based plastics. All the abhorring issues of regular petro-based plastics can be eradicated by using bio-based plastics.

2. Goals and Objectives

In this paper, an Analytic Hierarchic Process (AHP), based methodology is deployed to conduct a sustainability analysis of regular petro-based plastics and bio-based plastics on the basis of social, economic and environmental indicators. With non-renewable resources, non-biodegradability and other deleterious effects of regular petro-based plastics it is important to compare it with the newer bioplastics, which is biodegradable, environmentally friendly and uses renewable resources. The main contributions of this paper are as follows:

- To identify which factors affect the plastic manufacturing industry on the basis of social economic and environmental indicators.
- To measure the extent of those factors affecting the plastics manufacturing and uses.
- To help industrialists to focus their efforts on the right areas in order to gain maximum and sustainable output.
- To provide credible input for legislation toward sustainable manufacturing and use of plastics.
- To create public awareness regarding sustainable manufacturing and usage of plastics.

3. Literature Review

In past few years plastic has replaced many other materials especially metals due to its huge array of applications. The applications of plastics are about to increase with the emergence of new technologies. However, the qualities due to which it is favored over other material also make its disposal very difficult, especially in the regions without an adequate waste management and recycling structure. Furthermore, with the increasing plastic production, waste management system will also have to improve accordingly as most plastics usually do not break down naturally due to their chemical structure. Although some plastics are designed to break down and biodegrade under certain conditions but that may not occur in normal conditions.

3.1 Biodegradation

Biodegradation is the process of breaking down upon disclosure to ultra-violet radiation such as sunlight, dampness or water content, enzymes, wind abrasion, bacteria, or in certain cases pests, or insect attacks are also considered as forms of biodegradation or environmental degradation [9]. Certain forms of degradation needs that the plastic must be open by surface, while in some other forms it will be effective only if special conditions are present in the subject environment or landfills [9]. Plastipedia defines biodegradability as "the dissolution of a polymer in to its parts by the action of bacteria, fungi or other micro-organisms [10]. Any such material eventually converts to water, carbon dioxide, and energy [10]". Biodegradation is the dissolution of materials by bacteria, fungi, or other biological means. This term is generally used with waste management, biomedicine, ecology and natural environment. It is normally incorporated with eco-friendly products. The term biodegradable must not be confused with compostable as it means ingested by microorganisms only, while compostability requires certain specific conditions to break down the object.

3.2 Manufacturing Processes of Regular Petro-based Plastics and Bio-based Plastics

Figure 1 and Figure 2 illustrates the different stages in manufacturing of regular petro-based and bio-based plastics.

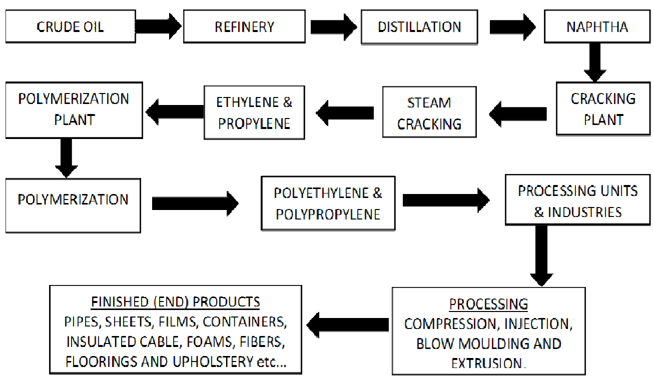

Figure 1: Flow chart of manufacturing process of petro-plastics

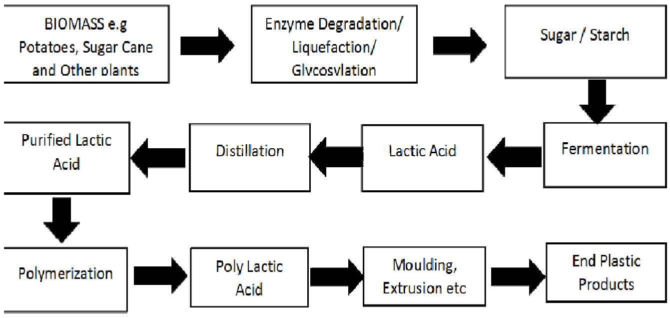

Figure 2. Flow chart of manufacturing process of bioplastics

4. Research Methodology

In this survey based research, factors were identified in the national plastic industry based on social, economic, and environmental indicators for achieving sustainability. First of all interviews were conducted at different levels of the plastic industry experts in order to deduce the social, economic and environmental indicators (criteria) to get an overview of their affects and their importance. After thorough research and discussion with the experts' 40 indicators suggested by Gupta [11] were selected as performance indicators, out of which only 30 were applicable in this research (shown in Figure 3). Next, a questionnaire was developed based on above mentioned indicators (criteria) in the system of the plastic industry. After the retrieval of questionnaires from 150 experts that have worked with industries manufacturing regular petro-based and bio-based plastics, the results were analyzed through a mathematical tool called Analytic Hierarchic Process (AHP) to find the more sustainable plastics. Data was collected on basis of these indicators (criteria) evaluated by Analytic Hierarchic Process (AHP). All resulting values in this research were checked to ensure their consistency through a measure called Consistency ratio.

4.1 Analytical Hierarchical Process

Analytic Hierarchic Process (AHP), is one of widely used mathematical model for making decisions in management of numerous businesses. Thomas L. Saaty developed this method in 1970's; that's why it's also called as Thomas Saaty method. The steps involved in the application of AHP are following. First the desired problem is converted into a hierarchical structure. A typical AHP is usually divided in to three levels that are objective, factors affecting and alternatives. Then pair-wise comparisons are drawn to obtain the comparison matrix. The comparison matrix is then used to compute the priority vector of the comparison matrix. The relative weight of elements in comparison matrix are then calculated. Usually, an element having a higher weightage is considered more important than the one with the lesser weightage. A normalized eigenvector then results in to a principal eigen value. When principal eigen value is found, a measure called Consistency Ratio (CR) is also calculated. If the value of consistency ratio is zero the matrix is considered consistent. If the CR value of a matrix is more than 0.1 then the process is repeated in order to acquire better and more consistent judgment [12,13,14,15,16].

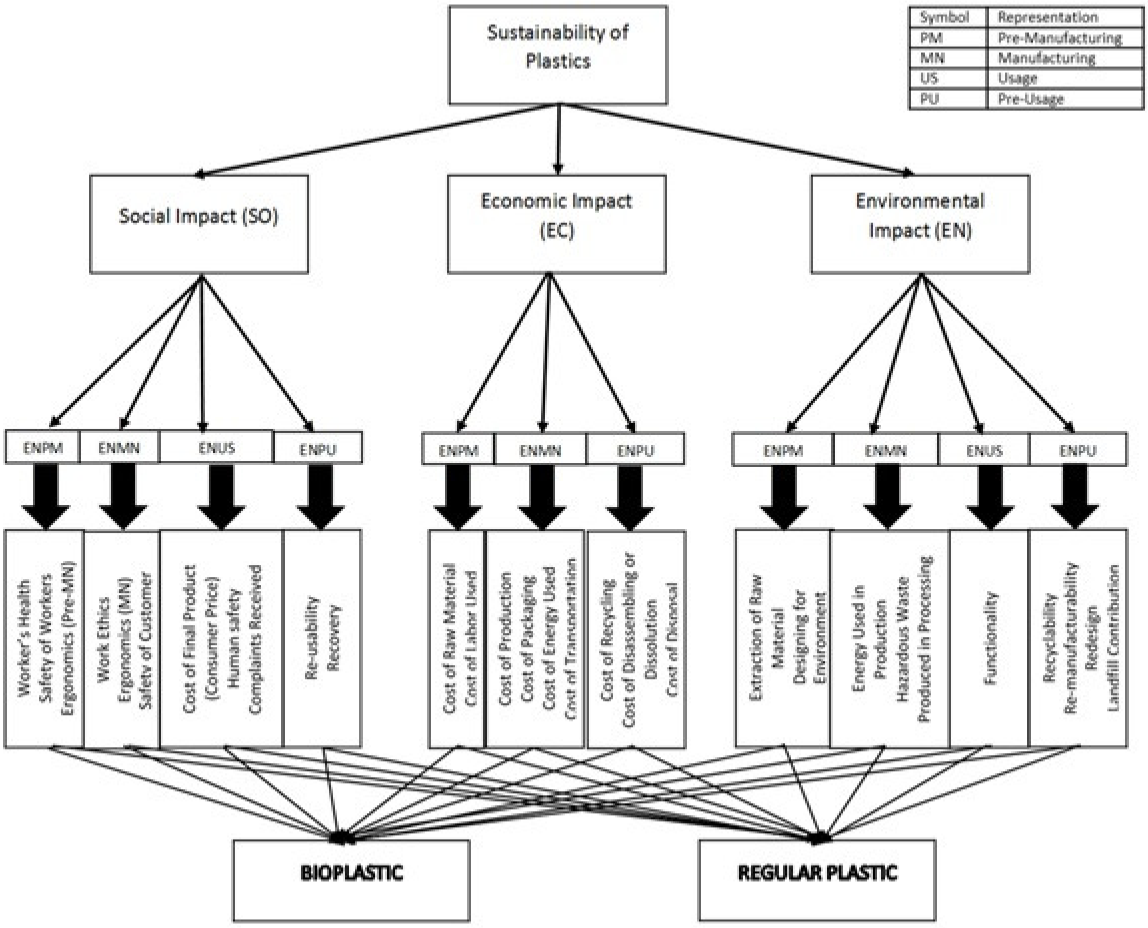

Figure 3: Hierarchy for AHP to select the best method used in plastic industry.

5. Results and Discussion

This portion describes the results in the shape of eigen values. Here, the focus will be on the factors which outstand in their impact on plastics. The eigen values for all indicators in manufacturing and usage of bio-based plastics and regular petro-based plastics, are given in Table 1.

Figure 4 sketches the results of Table 1 of both the processes. It is clear from the first eleven indicators (the economic indicators) that they slightly favor the manufacturing of regular petro-based plastics over bio-based plastics as in regular plastic manufacturing, the raw material is cheap, easy availability, more production due to relatively less expensive equipment deployed in industry. These economic indicators support the manufacturing of regular plastics because of the already widely available structure of the regular plastics industry and being the traditional way of manufacturing and being more abundant so far. Deviation from the conventional ways is always difficult to pursue. Some of them are in favor of bioplastics manufacturing such as Transportation cost as there are lesser imports, taxes and heavy import duties. That makes its price even less than regular petro-based plastic when analyzed holistically.

Table 1: Sustainability indicators with eigen values of bioplastics and petro-plastics.

Sr. No	Indicators	Bio Plastic	Petro Plastic
1	Cost of Raw Material	0.4556	0.5444
2	Cost of Labor Used	0.3456	0.6544
3	Cost of Production	0.4445	0.5555
4	Cost of Energy Used	0.3091	0.6909
5	Cost of Transportation	0.5085	0.4915
6	Cost of Recycling	0.6188	0.3912
7	Cost of Disassembling or Dissolution	0.7313	0.2687
8	Cost of Disposal	0.7276	0.2724
9	Cost of Remanufacturing	0.5611	0.4389
10	Cost of Final Product (Consumer Price)	0.3466	0.6534
11	Cost of Packaging	0.4798	0.5202
12	Material Extraction	0.5978	0.4022
13	Design for Environment (Toxicity)	0.8243	0.1757
14	Material Processing	0.6364	0.3636
15	Production Energy used	0.5884	0.4116
16	User Health	0.8472	0.1528
17	Safety of Customer	0.7296	0.2704
18	Hazardous Waste Produced in Processing	0.8303	0.1697
19	Functionality	0.3561	0.6439
20	Complaints Received	0.5327	0.4673
21	Recyclability	0.6067	0.3933
22	Re-manufacturability	0.5119	0.4881
23	Redesign	0.4689	0.5311
24	Landfill Contribution	0.9019	0.0981
25	Re-usability	0.5215	0.4785
26	Recollection	0.7825	0.2175
27	Worker’s Health	0.6214	0.3786
28	Safety of Workers	0.5154	0.4846
29	Professional Ethics	0.6879	0.3121
30	Ergonomics	0.6355	0.3645
	Average	0.5908	0.4095
	Sum	17.7249	12.2851

On the other hand, for regular plastic the raw material is imported from Far eastern countries or European countries, which constitutes at least half the prices of the actual finished product making transportation cost lesser for bioplastics.

When environmental indicators are brought under consideration, most indicators advocate the manufacturing and use of bioplastics. Indicators like “Landfill Contribution” is the indicator that has the highest value for bioplastic with eigen value of 0.9as it does not leech any harmful chemical to the environment. The indicator “Recyclability” also supports bioplastics as compared to petro-plastics because it requires great precision to recycle. For instance, a single colored bottle if mixed by mistake in a batch of 100,000 transparent plastic bottles can ruin the whole recycling process. At last when social indicators are brought under consideration, bioplastics clearly wins the race by a substantial margin as in such industries the overall mood is considerate of all the norms of the society. Socialites’ always consider health, safety, ergonomics and professional ethics paramount not only for workers inside the company but also for their customers and society that is why all the social indicators support the use and manufacture of bioplastics. Figure 4depicts the all these trends.

From Figure 4, it is concluded that bioplastics are considered more sustainable as per environmental and social indicators while regular plastics wins slightly in case of economic indicators. Figure 5 depicts the effects of all indicators when averaged. It can be seen that bio-based plastics show 59 % sustainability against the 41% sustainability of regular petro-based plastic.

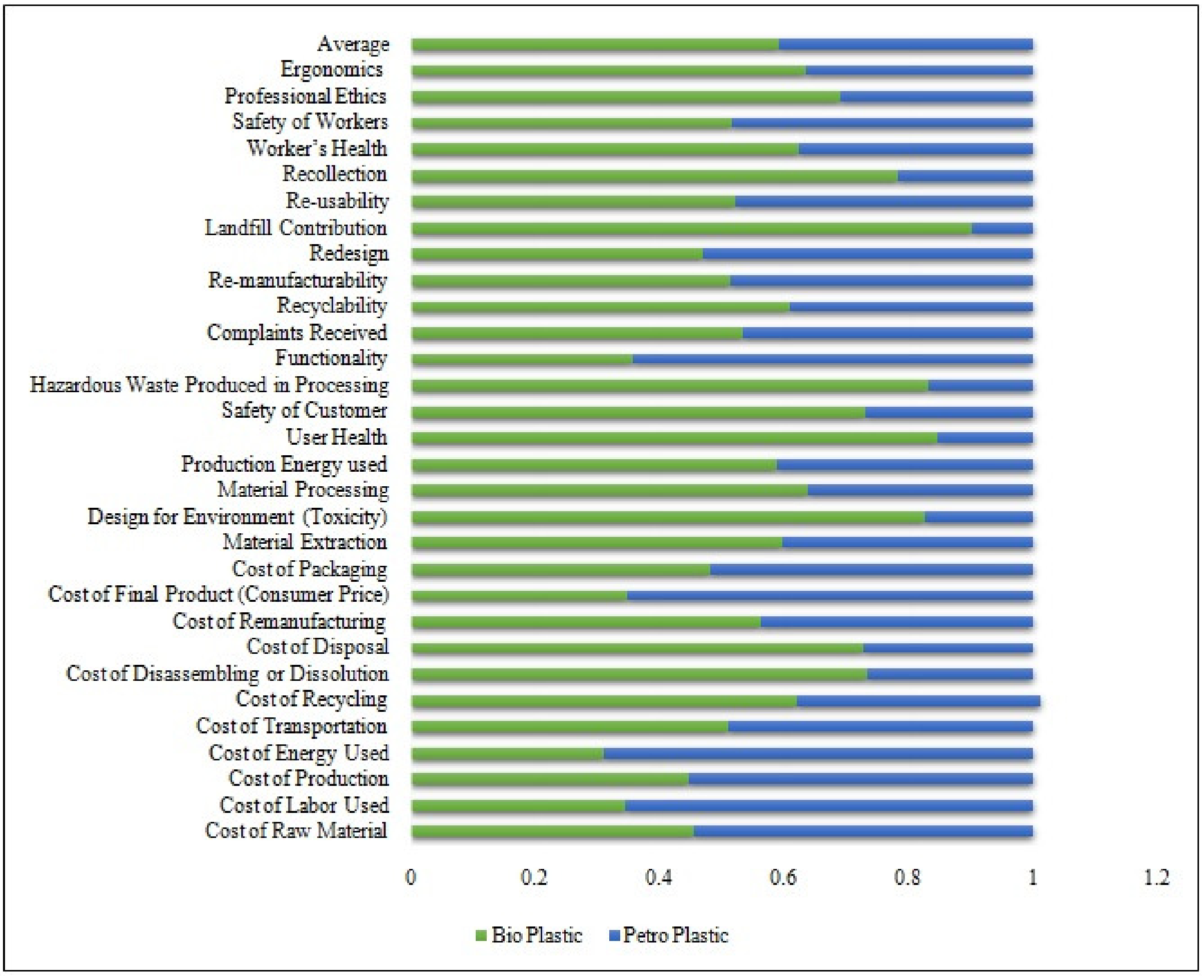

Figure 4: An illustration of trends of eigen values of indicators for sustainability in usage and manufacturing of petro-plastics and bioplastics.

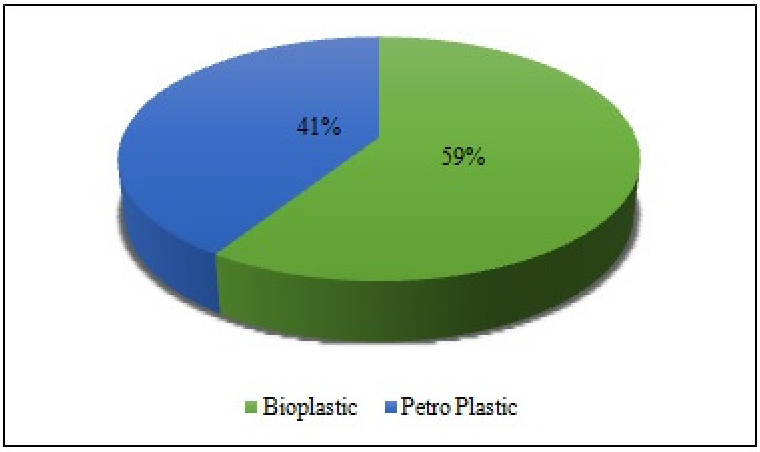

Figure 5: Average sustainability of regular petro-based plastics and bio-based plastics

6. Conclusions

This paper presented the idea of deducing a sustainable plastic manufacturing industry in Pakistan but the same methodology can be used in any region. For this purpose an Analytic Hierarchic Process (AHP) was used on the basis social, economic and environmental indicators or factors. A comprehensive questionnaire was designed with the help of experts in plastic industry, research centers and academia and then distributed among them. Economically, regular plastics were considered slightly more suitable due to the availability of a wide and abundant structure. Socially, bioplastic is yet again favorite for having a positive impact on its user and the society as there is less concentration on recyclability and safety precautions because of its healthy origin and structure. It is evident from the eigen value of indicator “Landfill Contribution” i.e., 0.9 for bioplastics that it is environmentally much more sustainable than the petro-plastics. Generally, the respondents favored the use and manufacture of bio-based plastics over petro-based plastics in view of most indicators and deemed more sustainable than the later. The overall result came out to be in favor of bio-based plastics with having the average eigen value of 0.59 as compared to the 0.41 eigen value of petro-based plastics. Future work will consider an elaborate cost analysis of both classes of plastics.

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