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SOLID WASTE MANGEMENT PRACTICES IN AUTOMOBILE INDUSTRIES

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Abstract

This article is devoted to a detailed analysis of waste management practices employed in automobile industries worldwide. This work also briefly touches upon the immense role of the automotive industry over any countries GDP growth. Although there are considerable disparities in prices and quality of vehicles produced world over, however the demand for automobile increases annually and in recent times many new and innovative brands of cars have emerged, globally. As this sector is advancing tremendously each year in its production and servicing aspects it is facing new challenges on the environmental front. Automobile industries produce hazardous organic and inorganic wastes on huge scales hence their ethical and responsible management is the absolute need of the hour. The present study, through the aid of secondary data, examines different approaches adopted by different countries for waste management; the goal of each country is to achieve 'zero waste generation'.

1. Introduction

Vehicles are the essential mode of transportation in today's world. Automobile industry consists of a wide range of companies and organizations which come up with new designs annually then develop and manufacture vehicles and are also involved in their marketing and sale. They manufacture self-powered vehicles such as passenger cars, farm equipment, trucks and other commercial vehicles**.** Currently automobile industry is one of the most important industries in the world with an immense influence on a country's economy. The industry plays a significant role in creating jobs, in 2017, globally 14 million people were employed within the automobile industry (ILO, 2021). Employment in the industry grew substantially between 2009 and 2017. In addition to direct employments, automobile industries also create additional jobs in adjacent sectors, a study in the USA concluded that for 1 direct job created in the automobile industry further 4 more jobs were created in another sector (Hill, *et al.,* 2010).According to the International Organization of Motor Vehicle Manufacturers, OICA, in 2017, 73.4 million cars and 23.84 million trucks were manufactured worldwide. Referring to more international estimates, the average twelve-monthly turnover of the world automobile industry is more than 2.75 trillion Euros which matches up to the 3.65% of the world GDP. In automobile industry, a 25% increase in production was observed from 2007 to 2017 (Saberi, 2018). The growth of this industry is a clear indicator of higher utilization of resources and incidentally, with higher use of resources comes generous amounts of wastes to deal with. National and international policies play an important role in the regulation and implementation of new legislations which push industries in the right direction by expecting them to spend more money on research and development for the improvement in their operational ethos (Kulkarni, *et al*., 2014).

The automobile industry has reformed cultural boundaries in a way that has revolutionized the mode of transportation and has enabled people and goods to travel farther, faster. Automobile industry in Pakistan is growing at a fast pace as well. It contributes 2.8% to Pakistan's GDP and 30 billion rupees to the national exchequer in terms of taxes and duties (Invest Government, Pakistan).The main objective of automobile industry in a country is to promote the production of vehicles and to strategically regulate their import and export. Following are the top ten exporters of automobiles and its parts according to the International Labor Office of Geneva's 2021 report:

1. European Union
2. Japan
3. USA
4. Mexico
5. Republic of Korea
6. Canada
7. China
8. Thailand

9. Turkey
10. Brazil

This industry utilizes natural resources like minerals, water and air in its production processes hence; local governmental and global laws are applied to the auto-industry to ensure ethical management of wastes produced during the manufacturing process. The waste after conventional treatment turns into sludge, ash or cake which contains residual impurities consisting of heavy metals and inorganic concentrates. All phases of a vehicle's life cycle impact the supply chain's environmental burden, from resource withdrawal, to manufacturing, use and reuse, recycling, or disposal. In order to improve their environmental performance Chinese manufacturers, employ numerous environmental practices including cleaner production as a means to achieve green supply chain management (GSCM), this aids them in lowering their environmental risks and impacts, while also raising their ecological efficiency (Zhu *et al.*, 2007).

Furthermore, end-of-life vehicles and the wastes birthing from them have vast environmental implications, henceforth, their management is a global concern. Efforts should be made to ensure that ELV wastes originating from automobile industries are recycled and used constructively in other industries as raw material and also in the generation of new automotive parts. A strong alliance between automobile and other industries should be encouraged to manage automobile and end-of-life vehicle wastes.

2. Types of Wastes Produced in Automobile Industry & The Environmental Problems Associated with Them:

According to estimates around 29 tons of waste is produced during the manufacturing of a car. Global Environment Centre indicates that Malaysia produces approximately 30,000 tons of waste every day and roughly about 900 rivers in Malaysia have been polluted because of improper dumping of solid waste generated by automobile industry (Wong, *et al*., 2018).

The manufacturing process of an average vehicle includes the utilization of a mixture of materials such as steel for body, glass for windows, rubber for tyers, lead containing batteries, wires of copper and other metals in trace amounts such as zinc, tin, platinum, cobalt and magnesium. Subsequently, the solid waste produced by automobile industry contains all kinds of materials including plastic, glass, rubber and metals. Other than that, paint waste is produced during coloring of vehicle.

The composition of the vehicles has changed tremendously over the past couple of years and so has the composition of wastes produced from automobile industry. The concentration of ferrous metals has decreased as the manufactures have started using lighter and relatively more fuel-efficient materials like, aluminum and thermosetting plastics. Henceforth, causing an increase in use of plastics, this is primarily due to the cheapness of plastic in terms of monetary value. Furthermore, it is light weight and corrosion resistant. Plastic contributes to battery, fuel tank, seats, bumper and dashboard, etc. in a vehicle (Sharma, *et al.,* 2016).

More use of plastic in manufacturing processes of automobiles is leading to mounting plastic waste. Disposal of plastic is an active issue observed worldwide. Burning of plastic leads to air pollution whereas disposal of plastic on land causes other problems as plastics do not degrade easily. If the plastic is chlorinated and contains other chemicals, those chemicals will leach down into the soil and contaminate the groundwater and runoff, this leads to water contamination. Plastic waste is also a hazard to biodiversity.

Glass is a high-tech material and is used for different purposes in the vehicles such as for safety, security and comfort ability of drivers. Automobile industry mostly uses toughened and laminated glass. The average glass material in a vehicle is 3% by its mass (Sharma, *et al.,* 2016).Automobile industry's waste contains shards of broken glass and glass powder. Waste glass powder effects the geotechnical properties of loose subsoil and it is also a threat to biodiversity.

Rubber is used primarily for the manufacturing of tyre in the automobile industry. Both natural and synthetic rubbers are used in automobile industry but synthetic rubbers are preferred over the natural rubber because they have high thermal stability and are more compatible with petroleum-based products. The rubber waste generated from automobile industry is a major environmental concern as the degradation of rubber releases chemicals into soil which leach down and contaminate the soil, groundwater and surface water. These chemicals are hazardous for the plant and aquatic species alike (Salihoglu, *et al.*, 2016). The management of rubber waste is getting difficult due to issues like, illegal dumping and stockpiling.

Metal waste is also produced in the automobile industry as steel of various qualities; aluminum, zinc and lead etc. are used in the manufacturing of a vehicle. Their disposal on land raises many environmental concerns. Metals are hazardous for plant and aquatic life.

3. Production of Solid Wastes in Automobile Industry:

A vehicle is manufactured after passing through following four major processes,

1. Stamping
2. Welding
3. Painting
4. Assembly

The processes of manufacturing of a vehicle starts from press shop where metal presses shape the metal planks cut from steel and aluminum rolls. Then the robots in the body shop weld the pressed metal parts together.

Firstly, smaller assembly units make the aluminum and steel parts which includes doors, underbodies or frame structures and then they are welded, glued and bolted together in the body shop. Afterwards the body is brought to a paint shop. Here the body is cleaned and de-greased in immersion baths and then coated with a layer of zinc phosphate. After this, 3 to 4 layers of paint are applied on the body to protect it from all kinds of environmental conditions and to give it an aesthetically pleasing color and look. Finally, all components such as steering wheels, armchairs, mirrors and headlights are installed, this is known as the assembly stage.

Hydraulic oils, contaminated barrels, contaminated absorbents and metal pieces are produced during the stamping process. Adhesive sealants, sludges, contaminated absorbents, metal and plastic pieces are produced after welding as waste products.

Wasted paint or varnish, paint containers, broken nozzles, phosphatizing sludges, waste adhesive sealants, adhesive containing sludges, contaminated barrels and contaminated absorbents are produced as wastes in the painting process.

Waste adhesive sealants, adhesive sludges, contaminated barrels, contaminated absorbents, hydraulic oils, glass pieces, plastic waste and steel residue are produced in the assembly process.

4. Waste Management

Various techniques are used all over the world to manage solid wastes. Different strategies and plans are devised and implemented to reduce waste generation rates and to ensure proper and safe waste disposal. Solid wastes are generally managed by recycling, processing, reuse, prevention, repacking, land filling, composting and incineration etc.

4.1 Reuse & Recycle

For the pursuit of achieving zero waste from automobile industries, the most promising way to adopt is reuse and recycles. Automotive shredder residue (ASR) is a probable by-product of car recycling, i.e., exclusion of all components, like, liquids and hazardous parts from the car and shredding of the body, this is followed by the retrieval of steel, iron, and non-ferrous scrap. European Union end-of-life vehicle directive encourages higher recovery and recycling rates, hence resultantly less amounts of automotive shredder residue end up in landfills. For the purpose of effective waste management, recycling of separated materials, dismantlement of bulky parts (bumpers, dashboards, seats, etc.) and methodical sorting of crushed or mixed materials is essential (Buekens, *et al.*, 2014).

As established above, waste recycling can actually help reduce waste quantity. It is possible that metal scraps and discarded material from automobile industries can be utilized to construct other machinery. Often scrap material achieved from vehicles is sold which leads to limited reuse and recovery and causes environmental nuisance. Proper recovery of ELV wastes can lead to up to 15,00,000 tons of steel, 180,000 tons of aluminum and 76 tons of rubber and plastics, which can all be reused to facilitate more creations and innovations (Sharma, *et al.*, 2016).

4.1.1 Management of Plastic Wastes

Plastics are durable, useful, cheap, easily moldable and recyclable material but in the environment, they are the biggest nuisance hence their recovery is absolutely essential. The use of plastics in vehicle manufacture has increased significantly over the years. 4% of world's oil and gas production is utilized for the production of plastics. After their disposal, as plastics are made of extremely stable polymers they accumulate in landfills and our environment and fail to degrade even after countless of years. The first step in reducing plastic wastes in automobile industry is to limit the amount of imported plastic and instead reuse the old parts from ELVs. Many vehicle dealers import parts like bumpers, lights, dashboard, etc. but do not carefully consider how these parts will be disposed and how if they are reused then it is not just environmentally sound but also a profitable stance to take according to the business point of view (Sharma, *et al.*, 2016).

4.1.2 Management of Glass Wastes

Vehicles contain two types of safety glass; one is laminated and the other is toughened. In automobile applications wastes arise during the production of side mirrors and windscreens. This waste is trimmed and recycled. Glass constitutes to only 1 part to overall material in the end-life vehicle, this amounts to 45000 tons and is mostly disposed of in landfills (Sharma, *et al.*, 2016). Glass can melt and be reused for the production of other materials; therefore, it is possible to dismantle the glass from ELV, collect and transport the glass to treatment facilities, purify the glass and obtain clean and reusable glass raw material called cullet. But the treatment and processing to make it reusable is extensive and expensive.

Cullet is used to make glass products and can be sold as a raw material. Cullet is a useful raw material as it is easy to melt in furnaces and cheaper than silica which is also employed as raw material. Reuse of culet is a good way to be environmentally friendly as it prevents other sources from being wasted to produce glass products (Sharma, *et al.*, 2016). Waste glass can be recycled to make Portland cement as it is the raw material having siliceous sources, waste glass can also be used as cement replacements once it is crushed into a powder form as they have very good pozzolanic reactivity. The environmental and economic benefits of using and recycling glass wastes originating from automobiles is tremendous.

Glass from an ELV is recovered by following this sequence,

4.1.2.1. Dismantling: Glass must be taken out of vehicle and classified according to type.

4.1.2.2. Cullet Processing: This processes glass on basis of contamination, continuity of supply, cost, durability, etc.

4.1.2.3. Shredding: In this step the whole vehicle is shredded and is distributed in to pieces from which glass and other useful material is singled out.

4.1.3 Management of Rubber Waste

Synthetic rubber is used in the manufacture of tyres. Addition of other substances like carbon black or zinc to synthetic rubbers makes it stronger and more durable. Tires in vehicles are made of synthetic rubber which is obtained from petroleum. Following ways can be adopted to effectively dispose of rubber wastes:

4.1.3.1. Land Filling: Tires are shredded before disposal to reduce size. 50% of wasted tires originating from automobile wastes in each country end up in landfills. Buried tires are a potential fire hazard. Fires in landfills due to tires cause uncontrolled pyrolysis of rubber and end up giving complex chemicals.

4.1.3.2. Crumbing: Another disposal method in which tires are cut until its rubber is turned into a crumb form which can be reused. It is the most effective method of recycling.

4.1.3.3. Devulcanization: This process converts rubber back into plastic state. This is achieved by unravelling the sulfur bonds existing in the molecular structure of rubber. By this method crumb rubber tires can be utilized as compounding.

4.1.3.4. Remold: Only 20% tires can be effectively remolded and it is a costly process financially as well as physically.

4.1.3.5. Incineration: Electricity can be generated by incinerating tires. However, this causes a lot of environmental pollution. Since tire is made up of rubber which is an organic material with high energy content, tires can be used to generate electric and heat energy. TDF (tire derived fuel) is used in cement kilns for heating purposes.

4.1.3.6. Pyrolysis: Tire pyrolysis converts wasted plastic and rubber into pyrolysis oil. This process breaks down large molecules into smaller ones. Under heat and a catalysts influence, tire decomposes to oil. Pyrolysis of polymer wastes can give us pyrolysis oil, Hydrocarbon gas and charcoal (Sharma, *et al*., 2016).

Although, landfilling of waste tires for is comparatively cheap and easy to achieve, but it is a waste of potentially valuable raw material which also leads to many other problems simultaneously. Tires pose a serious fire hazard causing atmospheric pollution, including zinc oxide, dioxins (toxic hydrocarbon) and poly-nuclear aromatic hydrocarbons which are all potent carcinogens. From all disposal options available for rubber waste disposal, pyrolysis poses a promising future. In California (USA), the Ethos Rubber Inc. built a trituration plant for tires retrieved from ELVs. The plant annually receives approximately 100,000 waste rubber tires. After recycling of tires materials like asphalt mixtures and new rubber products are manufactured. Furthermore, in Wolverhampton UK, an incinerator for the treatment of waste tires for production of electric power is installed (Sharma, *et al.,* 2000).

4.1.4 Management of Metal Waste

Most of the machines and their parts are made up of metal. Metal constitutes more than 70% of a vehicle and its parts. Steel and aluminum are the dominant metals used for construction of vehicles. The stages followed in ELV treatment facilities follow the following order,

4.1.4.1. Pre-Treatment: also known as de-pollution process, involves removal of bulky parts and other toxic materials, for example, operating fluids, battery, filters and airbags which contain explosive substances. Most of these parts are treated and then disposed of or are kept for recycle if they are useful.

4.1.4.2. Dismantling: In this process vehicle is dismantled and major parts are singled out. Engine is taken out directly and is sent for repair so that it can be reused.

4.1.4.3. Shredding: Shredding wastes reduces the volume of wastes. Parts from vehicle are shredded into smaller fragments and then to separate out useful material from junk different techniques like, magnetic separation, sink floating and eddy current belt methods are used. Following these processes, the materials are divided among three general categories, which are, ferrous metals (iron, steel), non-ferrous metals (aluminum, copper) and shredder residues. Ferrous and non-ferrous materials are further recycled as scrap metals (Sofia Poulikidou., 2010).

4.1.4.4. Shredder Residue: These constitute the 25% by weight of a vehicle that is fails to be recycled. Materials achieved from shredder residue fraction are more difficult to be extracted as they are made of different compositions with varying properties and characteristics. Extraction of useful material from the shredder residue is possible but it is economically draining. Therefore, the shredding residue is mostly classified as waste which is safely disposed of in landfills. But if there is a requirement of extracting out some useful material from shredder residue than techniques such as those mentioned above are use, namely, magnetic separation etc.

Table 1: Composition of Shredder Reside (Sofia Poulikidou. 2010).

Sr.No	Materials	Content by Weight (%)
1.	Polymers	27
2.	Urethane Foam	16
3.	Wood	3
4.	Glass	7
5.	Wire	5
6.	Fabric	15
7.	Iron	8
8.	Rubber	7
9.	Non-ferrous metals	4
10.	Minerals	8

4.1.5 Draining

As soon as end-life vehicles are sent to a junk yard the first thing done to them is draining. The engines of the vehicle are cleaned inside, out of any chemicals, tires are extracted, other fluids in the vehicle are drained and the corresponding parts in touch with those fluids are also removed out of the vehicle.

Draining is an important step in waste management of automobiles as the danger of pollution from fluids is high. The parts which are easily accessible from the exterior are extracted and pulled apart once draining is complete. These parts include, bumpers, plastic fuel tank etc. (Sharma *et al*., 2016).

4.1.6 Recycling End-Of-Life Vehicles

ELVs are also leading factor in unwarranted air, water and soil pollution due to their irresponsible and reckless dumping (Ahmed *et al*., 2014). ELVs are categorized into retired vehicles and natural ELVs. Retired vehicles are distinguished by the characteristics that they are impracticable vehicles, either because of physical failures caused by accidents, fire or vandalism. Although, natural ELVs are vehicles that fail the inspection process (Raja Mamat *et al*., 2016). Four end-points of ELVs, namely, irresponsible disposal, abandoned vehicles, poor management and roadworthiness, have been identified by the Malaysia Automotive Institute (Malaysia Automotive Institute, 2017).

Europe has conducted a wide range of research and policy making to address ELV challenges since the early 1990s. In September 2000, the EU ELV Directive (2000/53/EC) was instigated to order automobile and material manufacturers to meet certain specific goals which included,

1. Minimization of use of hazardous substances in the design stage
2. To design vehicles in a way which ensures reuse, recycling, disassembly and recovery of ELVs
3. Use of recycled materials in new vehicle production
4. Assurance that vehicles are free of hexavalent chromium, cadmium and mercury (Gerrard & Kandlikar, 2007).

In USA, end-of-life vehicle recycling is managed and controlled by market and not implemented through governmental regulations. National legislation bans dumping of hazardous solid waste which promotes ELV recycling and conscious waste management practices. Around 12.5 million ELVs were recycled in the USA during the 1980s (Staudinger *et al*., 2001). In 2014 the recycling association reported that properly managed recycling of wastes can reduce the average greenhouse gas emissions by 30,799,991 metric tons annually.

In contrast, ELV recycling in Mexico is market driven, valuable parts are recycled to make profits. No uniform ELV directive exists. This results in environmental degradation by, contamination prior to shredding, disposal of fluids in the sewage system, poor collection networks and abandoned ELVs (Wong, *et al*., 2018).

In Asian countries, ELV recycling law was first implemented in Japan in 2005. Later Korea also employed the Act for Resource Recycling of Electrical and Electronic Equipment and Vehicles in 2008 (Wong, *et al*., 2018).

5. Waste Management Plan

Any and all industries should have an effective waste management plan that ensures safe and environmentally sound disposal of wastes. The major wastes produced by automotive industry have been discussed above, they include, plastics, rubber, glass, fluids (coolants and lubricants). Effective management of these waste constituents can be beneficial for not just the environment but also the automobile industry. This is possible because most of the waste management in an automobile industry depends upon the basic concept of recycle and reuse. As discussed previously if plastics, metals, glass and rubber wastes are recycled and reused then the industry has to spend less on importing new parts every time a new vehicle is being manufactured. This makes the industry self-sufficient as it uses its own raw material to manufacture new goods. Another important step to ensure effective waste management is that the waste treatment and disposal costs should be economical and easier to perform. Furthermore, nowadays people have become very environmentally conscious and if they notice a leading brand being environment responsible then consumers feel satisfied and at ease. Following a waste management plan has been executed the detail of which have been discussed above.

6. Conclusion

It is essential to adopt ways that can effectively dispose wastes produced in any industry. We have discussed details of wastes generated at various process in vehicle manufacture and then ways to successfully dispose those wastes. Automobile industry is an ever-growing industry and with its exponential growth each year the wastes produced from these industries is also magnifying so it is absolutely essential to collect, recycle, reuse and dispose these wastes responsibly so that no further stresses are put on the planet.

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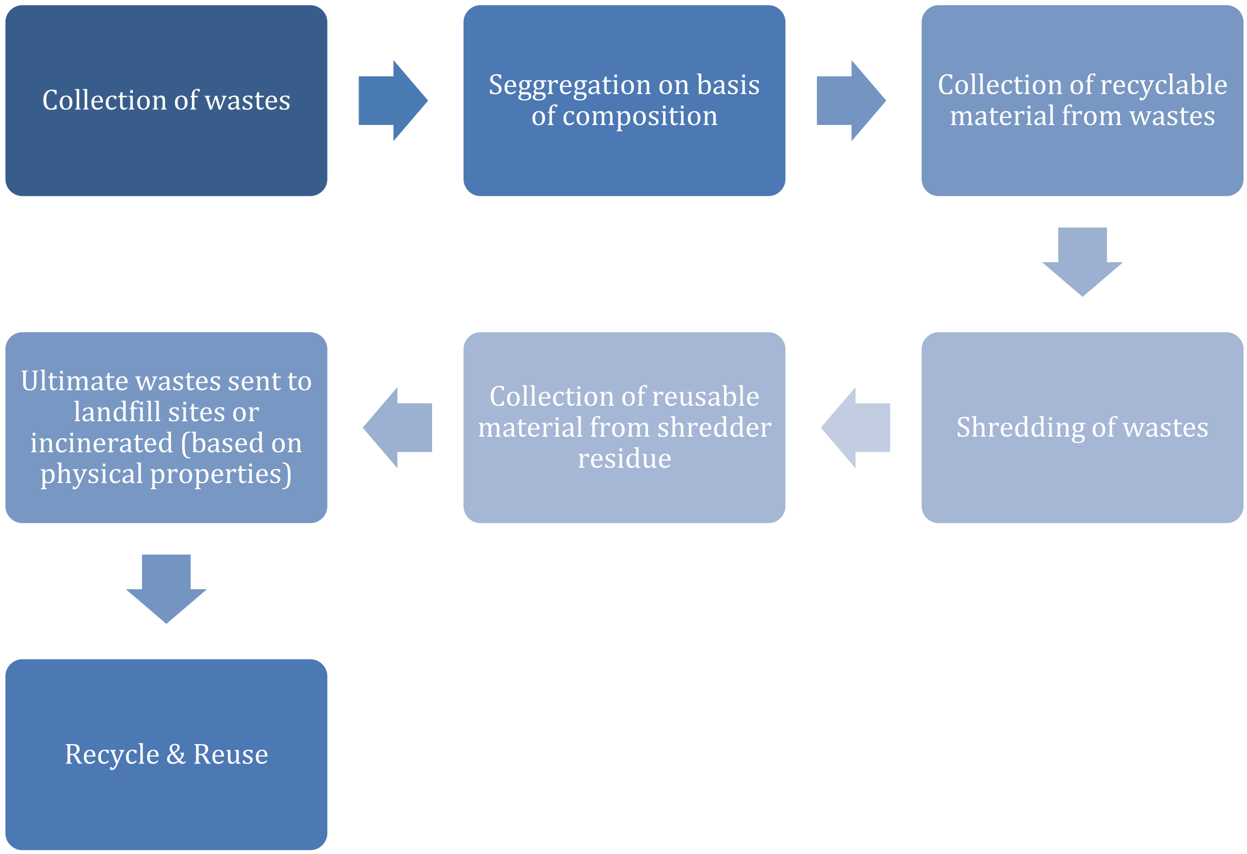

Figure 1: Waste Management Plan for An Automobile Industry.