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Recycling and Waste Management: A Path Towards a Sustainable Future

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Abstract

Waste management is one of the most pressing issues in the world today. This is due to the large amount of trash generated daily, which negatively impacts the environment and various forms of life. Effective waste management aims to dispose of garbage in a manner that minimizes its environmental impact. Waste management plays a crucial role in ensuring that garbage is disposed of in a manner that minimizes environmental impact. There is an urgent need for improved systems for recycling and reusing materials like metals, solvents, batteries, and plastics. As automobiles approach the end of their useful life, recycling becomes essential in reducing and ultimately eliminating waste. This highlights the pressing need for enhanced waste management strategies. Effectively recycling waste can significantly decrease and even eliminate waste generation over time.

Keywords: Waste management, recycling, reusing, metals, automobiles

INTRODUCTION

Automobiles are substantial consumers of resources. Currently, everything is changing, and automobile ownership is becoming more prevalent. Increasing automobile production is key to supporting the growth of the automotive sector. Many manufacturers recycle waste materials from cars to deal with supply problems that arise in the entire manufacturing system. Dangerous materials, such as metals, solvents, batteries, plastic, and glass, are reused and recycled to manage automotive waste. Recycling these materials may solve both resource depletion and environmental concerns. Currently, recycling accounts for over 75% of the vehicle weight. End-of-life vehicles promote recycling. It has been reported that 85% of the materials can be recycled and 95% can be reused [1–3]. The remainder, known as "auto shredder residue," is disposed of in landfills (ASR). The ASR consists primarily of plastics (20–27%), rubbers (18–22%), metals (4–15%), foams and fluff (40–52%), plastics (20–27%), rubbers, and plastics. Currently, there is no cost-effective method for recycling plastics and foam [4]. End-of-life vehicle (ELV) recycling is essential to return valuable materials and resources from old vehicles. Consequently, recycling experts in the modern automotive industry have devised several ways to improve their performance [5, 6].

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COMPOSITION OF VEHICLES

A typical automobile has steel body construction, glass windows, rubber seals, lead batteries, copper wiring, and trace quantities of cobalt, zinc, magnesium, tin, and platinum (Figure 1) [7]. In recent years, the composition of vehicles has changed drastically. Modern vehicles are made of lighter materials, such as aluminum and engineering plastics, which use less gas. Consequently, the amount of ferrous metal dropped considerably.

Metals production consumes far more energy than plastic production. In recent years, plastics have gained popularity in the automobile industry owing to their corrosion resistance, lightweight properties, and low cost. However, the proportion of iron and steel in domestic automobiles has dramatically decreased. In the past, steel, aluminum, and metal alloys were significant in making cars. However, some steel has been replaced with aluminum to reduce CO_2 emissions and fuel use. Steel is an essential component of the automotive industry because it is strong, challenging, and malleable. However, it still needs to be more convenient, and manufacturers have cut back on how much they use it. Owing to the use of composite materials, designers in numerous engineering disciplines have broadened their horizons. Composites are essential because they have a high ratio of mechanical strength to weight, and high impact strength compared to traditional materials. Composites are often used in aircraft, where most parts must be light and robust [8]. By replacing traditional metals with lighter-density metals, plastics, and other composite materials, the weight of older vehicles has been significantly reduced. For example, aluminum or magnesium can be used to create engine blocks made of cast iron. This makes the vehicle lighter and is one of the few parts that cannot be made from plastic. Body panels, which account for approximately 60% of a vehicle's total weight, may be much lighter with plastic.

WASTE MANAGEMENT

Many steps have been taken and are still being taken to manage solid waste on a global scale. Experts have developed and offered waste reduction strategies. Some of the most common ways to deal with trash are reducing, preventing, recovering, repackaging, composting, recycling, reusing, putting trash in landfills, and burning trash [9–11]. Recycling and reuse are used interchangeably when discussing waste management. Material recycling may help to decrease and eventually eliminate waste. Using rejected or old metals from industry and metal scrap dealers to manufacture equipment can help reduce waste. It is evident from their components that these metals have become feedstock [12]. Although the number of vehicles on the road has grown significantly in the last ten years, the problem of car waste has yet to be considered. There are no laws governing the recycling and disposal of ELV, nor is there an infrastructure or organized system for collecting, disassembling, shredding, and processing vehicle scraps. Low-tech businesses are crushing and selling old cars, which hurts the economy and environment. Effective recycling processes and systems are anticipated to recover approximately 15,000,000 metric tons of steel waste, 180,000 metric tons of aluminum, and 75,000 metric tons of plastic and rubber by 2025. The amount of waste to be disposed of is approximately 25,000 metric tons, with an annual increase of 10% [13]. The Pollution Control Board of many developing countries wants to do more than deal with the air and noise pollution caused by passenger cars. They also want to control the waste of dangerous materials at auto service stations [14].

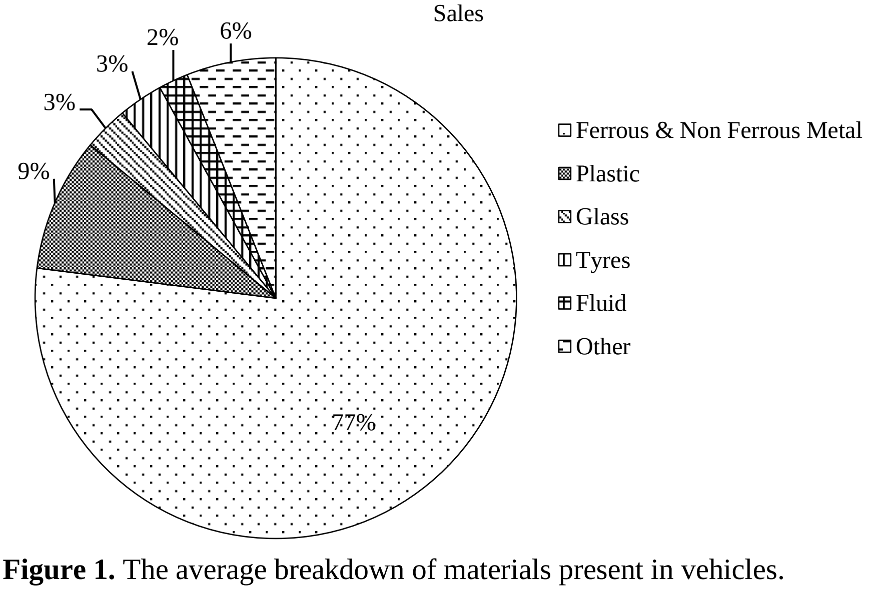

Figure 1. The average breakdown of materials present in vehicles.

PLASTIC WASTE MANAGEMENT

Plastics are inexpensive, lightweight, durable, and can be easily molded into various products. The amount of plastic produced and used in automobiles has increased dramatically in recent years (Figure 2). However, the current levels of use and disposal contribute to several environmental problems. Approximately 4% of the world's oil and gas output is used as feedstock for plastics, and another 3–4% is used to provide energy for their production. Because of the durability of polymers, many unwanted plastics that have reached the end of their useful lives end up in landfills and natural areas worldwide.

Since many ways have been found to produce polymers from petroleum ingredients, the industry has grown by leaps and bounds. Plastics provide substantial weight, durability, and cost benefits compared to many other materials [15, 16]. At first, the parts may be picked by hand, but the people doing it need to be trained in how to do it correctly. The first step toward reducing plastic waste in automobiles is to limit the number of imported components entering the country in favor of recycling obsolete ELV parts. Many car dealers import parts, such as bumpers, lights, and dashboards, to make the most money. However, they often need to think more carefully about how these parts will be destroyed or handled after they have completed their original job.

Recycling is considered one of the most important ways to reduce adverse effects and is one of the most effective methods in the plastics industry. Recycling allows us to use less oil, burn less carbon, and eliminate less trash. Recycling can be achieved by reducing the number of materials used by downsizing or reusing products, using alternative materials that are beneficial to the environment, and recovering energy for fuel. In addition, natural resources are preserved when waste is recycled or reused, because the raw materials may be remelted, ground, or formed into new forms. This event is primarily suitable for the entire planet because gases do not have borders, and if the small amount of oil removed is recycled or reused, it will be saved for future use [17–21].

GLASS WASTE MANAGEMENT

The safety, security, comfort, and sustainability of modern living depend on glass, a high-tech material used in the building, transportation, and vehicle sectors. Typically, 3% of the bulk of a vehicle consists of glass. Toughened and laminated safety glasses are found in vehicles. Glass is often mixed with functional parts, such as plastic interlayers, when laminating safety glass, ceramic inks, silver-printed electrical connections, encapsulating materials, and fastening clips. This was done to meet the glazing module requirements of the vehicle manufacturer [22]. Thinner and more fragile than structural flat glass, vehicle glass is toughened to enhance durability and safety. While safety is a priority, one of the primary reasons for using thinner glass is to decrease vehicle weight. All the components and materials must be considered.

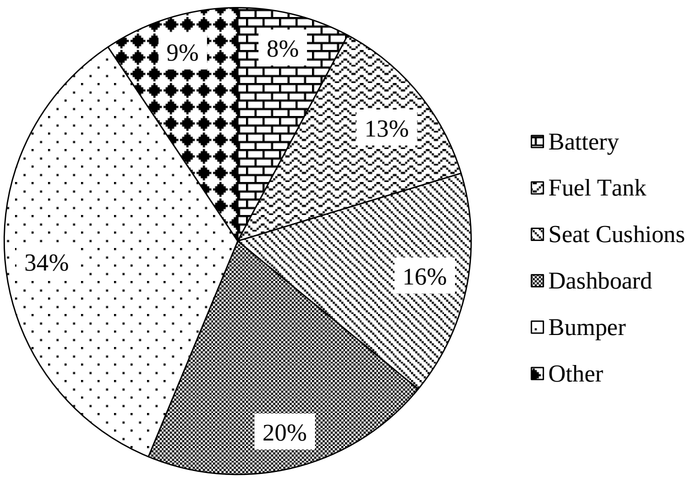

Figure 2. Average distribution of plastics in vehicles.

Moreover, automotive glasses have been subject to rigorous scrutiny. Owing to the proximity of the passengers to the glass for longer durations, any defects will be far more noticeable. Occasionally, slight optical defects result in structural flaws and early failures. In automobile applications, waste occurs when contoured side panels and windscreens are used. These materials were recycled and reused. The collection of these industrial effluents has received little attention. Glass makes up approximately 3% of the weight of all materials in cars that are no longer being used. On a nationwide basis, this amount might amount to up to 45,000 metric tons each year, the majority of which is now landfilled. Glass is a renewable resource that can be melted and added to aggregate after proper steps are taken. However, glass recycling and treatment are complicated, expensive, and unsustainable. Therefore, it is possible to get the Glass out of ELV, recover and transport it to treatment facilities, clean the glass, and make a "cullet" that is perfect and can be used again. Cullets can be reused to make glass products and used as raw material substitutes in other industries. First, the cullet is cheaper than the raw material (silica) and requires less electricity to melt [23]. In addition, it prevents people from taking out, transporting, processing, and using a considerable amount of natural resources to make glass products. Therefore, the reuse of cullets has several environmental advantages. The three main processes to recycle ELV glass are dismantling, cullet processing, and shredding [24–26].

Dismantling

The glass should be removed from the automobile and classified by type depending on its intended end use, such as laminated or silver-printed rear windows. On average, this process took approximately five minutes per vehicle.

Cullet Processing

The cullet processor chooses from the different types of waste glass available, considering the level of contamination, stability of supply, costs, and selling prices.

Shredding

This technique involves crushing and shredding the entire vehicle into pieces, which are then separated into product streams. Glass still in a car is mixed with stones, bricks, and other materials [27].

RUBBER WASTE MANAGEMENT

Natural rubber and synthetic rubber are two types of rubber. Monomers, such as styrene, chloroprene, isobutene, and 1,3-butadiene, can be combined to produce synthetic rubber. Although natural rubber is more stable at high temperatures and works better with compounds made from petroleum, synthetic rubber is usually better. In addition, synthetic rubber can be altered by the addition of various monomers. Synthetic rubber has no leftover impurities, such as natural rubber, so it can be mixed with other materials to change its properties [28].

Carbon black and zinc are two common additives that are used to change how something works. Consequently, synthetic rubber is often used to produce more durable materials such as hoses, belts, and tires. Changing the percentages of sulfur or additives, for instance, will result in different types of tires for various uses [29]. The rising demand for automobiles has led to the development of a vast quantity of waste tires, and their effective and ecologically friendly disposal has become a burden for many local and national governments worldwide. The increasing price of scrap tire management has led to illegal dumping and stockpiling by local governments [30–33]. They are often disposed of in landfills using inappropriate methods such as illegal dumping. Waste minimization requires recycling, reuse, and the invention of innovative toxicity reduction technologies [34]. The waste management hierarchy comprises reducing, reusing, recycling, placing trash in a landfill, and recovering waste through physical, biological, and chemical processes.

Current Methods for Disposing of Automobile Tires

Current waste tire disposal methods include landfilling, shredding, devulcanization, remolding, incineration, tire-derived fuel production, and energy recovery through pyrolysis.

Landfill

Discarded tires were shredded before disposal to reduce their size for landfill disposal. Approximately half of all discarded automotive tires are disposed of in landfills worldwide. Tires dumped in landfills cause fire threats at several locations. In addition, these incidents result in uncontrolled pyrolysis of tires, which generates a complicated chemical combination. Our understanding of the long-term leaching of organic compounds from landfills is minimal.

Crumbing

Crumbing is an alternative disposal method. In this procedure, the tires are sliced in stages until the rubber is in a state that may be used in various applications. There are a variety of potential uses for tire shreds, but only approximately 25% of them are now being used. Therefore, it may be the most efficient approach for recycling without producing any additional direct pollution [35].

Devulcanization

Devulcanization is the transformation of rubber from its thermoset, an elastic state, to its plastic, formable state. This was achieved by separating the sulfur bonds in the structure of the molecule. With a proper devulcanization procedure, a much higher proportion of old tire crumb rubber can be compounded [31].

Remolding

Remolding is an expensive operation, both economically and physically, for the manufacturer. In addition, only a few designs—approximately 20% of tires—are appropriate for remolding; this percentage may grow by 5% in the future [35].

Incineration

Waste tires may be used to generate electricity via incineration. Nonetheless, this technology requires significant investment and produces significant pollutants. In addition, thermal recovery in cement kilns and power plants is an effective method for disposing of waste tires; thus, legislators may require specific users to refurbish their emission systems [36].

Tire-Derived Fuel

Because scrap tires are made of rubber, an organic substance with high energy content, they can generate heat and electricity. Tire-derived fuel (TDF) is the term given to the material derived from tires for this purpose. Cement kilns predominantly use TDF for heating [37].

Pyrolysis

Tire pyrolysis is a way to turn old tires and plastic into oil, carbon black, and hydrocarbon gas. Pyrolysis is a process in which large molecules are broken down into smaller molecules [38, 39]. Heat and catalysts were necessary for the reaction. The tires were dissolved in gasoline. Pyrolyzing polymer waste makes it feasible to recover its value in the form of pyrolysis oil, hydrocarbon gas, and charcoal [40].

METAL WASTE MANAGEMENT

Metals, in particular, are solid waste from industrial retooling, broken or grounded equipment, building waste, car scraps, office scraps, spare parts left behind, etc. Metal, the primary material used to construct the world's infrastructure, comprises the majority of machinery, equipment, and tools. Steel and aluminum are the primary structural materials. More than 70% of all known vehicle parts are made of steel or aluminum [41]. Several grades of steel are used as the principal materials for the vehicle's structure, chassis, and body components. In addition to the body, chassis, and engine components, aluminum is used for interior components and airbags. Other metals and parts are found in smaller amounts but are required to make the extra parts of the vehicle. For example, copper produces cables, radiators, and connections [42]. Pb and Zn are additional components of automobiles. The principal use of lead is in automobile batteries, but it is also used as an alloying agent in steel and aluminum to improve its machining properties.

In contrast, Zn is used as a coating for steel to protect it against corrosion [43]. When used, the vehicle becomes debris, similar to other products. According to these rules, over 90% of abandoned automobiles are picked up and processed [44]. Several steps are then taken to separate the parts and materials that can be reused or recycled while reducing waste. Currently, approximately 80% of the vehicle volume is recycled or reused. Approximately 65–70% of this rate is due to its metal parts, and the other 10–15% is due to parts that have been taken apart, recycled, or used for something else [45, 46]. The following steps occur at end-of-life treatment facilities: pretreatment, dismantling, shredding, and shredder residue treatment [47, 48].

Pretreatment

Vehicle components containing dangerous and toxic substances were eliminated during pretreatment. Fluids, such as oils and fuels, batteries, oil filters, parts that contain mercury, and devices with explosive chemicals, such as airbags, are all examples of these types of parts. Most of the objects collected at this point are recycled or processed further before they are thrown away according to the rules [42].

Dismantling

A car is separated into its essential parts, and the parts that can be reused or recycled are removed. Pieces worth money, such as engines or other body parts, can be used immediately after specific restoration steps. In addition, after the car is removed, its parts are separated into different groups of materials and parts before they are recycled. Examples include tires, glass components, catalytic converters, and other commonly observed components [45].

Shredding

The goal of shredding is to reduce the amount of trash that does not need to be present while separating the materials into more uniform pieces that can be recycled. Vehicles were broken into smaller pieces. Mechanical and physical methods such as magnetic separation, eddy current belts, and sink floating are used to further separate different materials based on their type and features. After these steps, the materials were placed into three groups: ferrous metals (iron and steel), nonferrous metals (aluminum and copper), and shredder waste. The components of scrap metal are ferrous and nonferrous metals.

Shredder Residues Treatment

Shredder residues (SR) make up the remaining 25% of the vehicle’s weight that is not recycled. The SR fraction comprises several compounds with different properties, making it more difficult to separate the parts [49]. Although they are only sometimes financially practical, these substances can be removed and recycled. Following the final processing, most of the SR part is disposed of in landfills. Post-shredding methods improve the separation and recycling rates by eliminating residual metals and other components of SR, such as plastics and minerals. The physical and mechanical separation techniques were used again. Polymer waste is discarded from landfills in most countries worldwide. With more plastics and composites being used in vehicles in the future [50], the SR method would become much less helpful. Therefore, it is becoming increasingly essential to increase the number of ways SR can be used and the rate of recovery [51].

DRAINING

This is the primary step taken by automobiles to enter an ELV. First, the vehicle is drained after cleaning the exterior and engine compartments and removing the tires. Next, the vehicle or automotive lubricants and fluid-containing components were removed. Drainage is necessary because of the risk of fluid contamination in the storage space and the remaining waste. After draining, body pieces such as bumpers, plastic fuel tanks, and auxiliary systems are easily accessible from the outside and disassembled [27].

RESULT AND DISCUSSION

Every industry should implement a waste management strategy to ensure safe and environmentally acceptable disposal. Plastics, rubber, glass, and fluids (coolants and lubricants) are the primary substances produced by the automobile sector. Therefore, effective waste management may benefit the environment and the automotive industry. This is achievable because most waste management in the vehicle sector is based on fundamental principles of recycling and reuse. As previously noted, if plastics, metals, glass, and rubber waste are recycled and reused, the automotive industry imports fewer new components whenever a new vehicle is produced. As a result, the industry is self-sufficient and employs raw materials to produce new products. To ensure successful waste management, waste treatment, and disposal must be cost-effective and straightforward. Moreover, people are today very environmentally concerned, and if they see a top brand as being ecologically responsible, they feel satisfied and relaxed.

CONCLUSION

This review article examines new ways to recycle waste that protect the environment, improve technology, and ensure that everyone lives in a safe and prosperous place. The disposal of obsolete vehicles must be handled with restrictive standards. By recycling, reusing, and reducing waste at the top of the waste hierarchy, a framework for sorting trash was developed. How well do these methods work and what benefits do they offer depending on the type of operation, amount of time needed, and budget for the procedure? The problem of how to deal with automotive waste on a global scale can be solved using single-use materials that reduce carbon emissions and can be easily recovered and reused when they are no longer helpful.

REFERENCES

1. Nawrocky M, Schuurman DC, Fortuna J. Visual sorting of recyclable goods using a support vector machine. CCECE 2010, Calgary, AB, Canada. 2010. pp. 1–4. doi: 10.1109/CCECE.2010.5575231.
2. House BW, Capson DW, Schuurman DC. Towards real-time sorting of recyclable goods using support vector machines. Proceedings of the 2011 IEEE International Symposium on Sustainable Systems and Technology, Chicago, IL, USA. 2011. pp. 1–6. doi: 10.1109/ISSST.2011.5936845.
3. ReportBuyer. Waste management in the automotive industry 2015–2019. [Online]. PRNewswire; 2015. Available from: https://www.prnewswire.com/news-releases/waste-management-in-the-automotive-industry-2015-2019-300173788.html
4. Sivakumar GD, Barnabas SG, Anatharam S. Indian automobile material recycling management. Int J Innov Res Sci Eng Technol. 2014;3:2754–8.
5. Cui J, Roven HJ. Recycling of automotive aluminum. Trans Nonferrous Met Soc China. 2010;20:2057–63. doi: 10.1016/S1003-6326(09)60417-9.
6. Yu C, Chau KT. Thermoelectric automotive waste heat energy recovery using maximum power point tracking. Energy Convers Manag. 2009;50:1506–12. doi: 10.1016/j.enconman.2009.02.015.
7. Nyamekye P. Re-use and recycling of automobile plastics – a step to manage plastic waste in Ghana. [Degree Thesis]. Helsinki: Arcada University of Applied Sciences; 2012.
8. Vivekanandan R, Prakash M. Selection of alternative material for car roof panel. Second International Conference on Current Trends In Engineering and Technology - ICCTET 2014, Coimbatore, India. 2014. pp. 32–40. doi: 10.1109/ICCTET.2014.6966259.
9. Magram SF. Worldwide solid waste recycling strategies: a review. Indian J Sci Technol. 2011;4:692–702. doi: 10.17485/ijst/2011/v4i6.12.
10. Kofoworola OF. Recovery and recycling practices in municipal solid waste management in Lagos, Nigeria. Waste Manag. 2007;27:1139–43. doi: 10.1016/j.wasman.2006.05.006.
11. Morakinyo AD, Vershima AN. Recycling of scrap solid (metal) industrial waste in fabrication of tile making machine as a strategy in waste management in Kaduna, Nigeria. Pac J Sci Technol. 2014;15:47–57.
12. Hamer G. Solid waste treatment and disposal: effects on public health and environmental safety. Biotechnol Adv. 2003;22:71–9. doi: 10.1016/j.biotechadv.2003.08.007.
13. Groenewegen P, Hond FD. Product waste in the automotive industry: technology and environmental management. Bus Strateg Environ. 1993;2:1–12. doi: 10.1002/bse.3280020101.
14. McKenrick LL, Ii K, Lawrence B, Kaufmann M, Marshall M. Helping the auto repair industry manage hazardous wastes: an education project in King County, Washington. J Environ Health. 2003;66:9–14.

15. Andrady AL, Neal MA. Applications and societal benefits of plastics. Philos Trans R Soc Lond B Biol Sci. 2009;364:1977–84. doi: 10.1098/rstb.2008.0304.
16. Thompson RC, Swan SH, Moore CJ, Vom Saal FS. Our plastic age. Philos Trans R Soc Lond B Biol Sci. 2009;364:1973–6. doi: 10.1098/rstb.2009.0054.
17. Chanda M, Roy SK. Plastics technology handbook. 4th ed. Boca Raton (FL): CRC Press; 2006. p. 896. doi: 10.1201/9781420006360.
18. Andrady AL, editor. Plastics and the Environment. Hoboken (NJ): John Wiley & Sons; 2003.
19. Fletcher BL, Mackay ME. A model of plastics recycling: does recycling reduce the amount of waste? Resour Conserv Recycl. 1996;17:141–51. doi: 10.1016/0921-3449(96)01068-3.
20. Swift G. Degradable polymers and plastics in landfill sites. In: Mark HF, editor. Encyclopedia of Polymer Science and Technology. Hoboken (NJ): John Wiley & Sons; 2015. p. 1–13. doi: 10.1002/0471440264.pst457.pub2.
21. Patel M, von Thienen N, Jochem E, Worrell E. Recycling of plastics in Germany. Resour Conserv Recycl. 2000;29:65–90. doi: 10.1016/S0921-3449(99)00058-0.
22. Schorcht F, Kourti I, Scalet BM, Roudier S, Sancho LD. European Commission best available techniques (BAT) reference document for the production of cement, lime, and magnesium oxide. Ind Emiss Dir 2010/75/EU (Integr Pollut Prev Control). JRC Reference Reports. Luxembourg: Publications Office of the European Union; 2013. p. 506.
23. Ministry of Economy, Trade and Industry. Handbook on Resource Recycling Legislation and 3R Trends in 2003. Tokyo: Ministry of Economy, Trade and Industry; 2003. p. 1–85.
24. Butler J, Hooper P. Dilemmas in optimising the environmental benefit from recycling: A case study of glass container waste management in the UK. Resour Conserv Recycl. 2005;45(4):331–55. DOI: 10.1016/j.resconrec.2005.02.006.
25. Reindl J. Reuse/Recycling of Glass Cullet for Non-Container Uses. Madison (WI): Dane County Department of Public Works; 1995.
26. Shi C, Zheng K. A review on the use of waste glasses in the production of cement and concrete. Resour Conserv Recycl. 2007;52(2):234–47. DOI: 10.1016/j.resconrec.2007.01.013.
27. Sharma P, Sharma A, Sharma A, Srivastava P. Automobile waste and its management. Res J Chem Environ Sci. 2016;4(2):1–7.
28. Kumar CSSR, Nijasure AM. Vulcanization of rubber. Resonance. 1997;2(4):55–9. DOI: 10.1007/BF02919629.
29. REDCO. (2025). Essential Uses of Rubber Products. [Online] REDCO. Available from: https://www.redco1.com/resources/news/essential-uses-of-rubber-products
30. Sharma VK, Fortuna FA, Mincarini MA, Berillo M, Cornacchia GI. Disposal of waste tyres for energy recovery and safe environment. Appl Energy. 2000;65(4):381–94. DOI: 10.1016/S0306-2619(99)00085-9.
31. Reschner K. Scrap Tire Recycling: A Summary of Prevalent Disposal and Recycling Methods. Berlin: Tire Engineering; 2008. Available from: https://entire-engineering.de/Scrap_Tire_Recycling.pdf.
32. Staudinger J, Keoleian GA. A Summary of Prevalent Disposal and Recycling Methods, Design for Recycling. Ann Arbor (MI): Center for Sustainable Systems, University of Michigan; 2001.
33. Shaw D. Why is recycled rubber not used in tyres? Eur Rubber J. 2011 Sep-Oct;34–7. Available from: https://www.lehightechnologies.com/documents/European_Rubber_Journal_Sept_Oct_2011.pdf.
34. de Marco Rodriguez I, Laresgoiti MF, Cabrero MA, Torres A, Chomón MJ, Caballero B. Pyrolysis of scrap tyres. Fuel Process Technol. 2001;72(1):9–22. DOI: 10.1016/S0378-3820(01)00174-6.
35. Murugan S, Ramaswamy MC, Nagarajan G. The use of tyre pyrolysis oil in diesel engines. Waste Manag. 2008;28(12):2743–9. DOI: 10.1016/j.wasman.2008.03.007. PubMed: 18499428.
36. Aydın H, İlkılıç C. Optimization of fuel production from waste vehicle tires by pyrolysis and resembling to diesel fuel by various desulfurization methods. Fuel. 2012;102:605–12. DOI: 10.1016/j.fuel.2012.06.067.

37. Doğan O, Çelik MB, Özdalyan B. The effect of tire derived fuel/diesel fuel blends utilization on diesel engine performance and emissions. Fuel. 2012;95:340–6. DOI: 10.1016/j.fuel.2011.12.033.
38. Roy C, Chaala A. Vacuum pyrolysis of automobile shredder residues. Resour Conserv Recycl. 2001;32(1):1–27. DOI: 10.1016/S0921-3449(00)00088-4.
39. Williams PT, Brindle AJ. Fluidised bed catalytic pyrolysis of scrap tyres: Influence of catalyst:tyre ratio and catalyst temperature. Waste Manag Res. 2002;20(6):546–55. DOI: 10.1177/0734242X0202000609. PubMed: 12549667.
40. Oracle World Wide. Recycling Pyrolysis Plants. Pyrolysis Tire Recycling Plant. 2010.
41. Sullivan JL, Williams RL, Yester S, Cobas-Flores E, Chubbs ST, Hentges SG, Pomper SD. Life cycle inventory of a generic US family sedan overview of results USCAR AMP project. SAE Trans. 1998;1909–23.
42. Lundqvist U, Andersson B, Axsäter M, Forsberg P, Heikkilä K, Jonson U, et al. Design for Recycling in the Transport Sector – Future Scenarios and Challenges. CPM Report 2004:7. Göteborg, Sweden: Chalmers University of Technology; 2004. Available from: https://www.lifecyclecenter.se/wp-content/uploads/2004_7-Design-for-Recycling-in-the-Transport-Sector-%E2%80%93-Future-Scenarios-and-Challenges.pdf.
43. Sander K, Lohse J, Pirntke U. Heavy Metals in Vehicles [Final Report]. Directorate General Environment, Nuclear Safety and Civil Protection of the Commission of the European Communities. Ökopol - Institut für Ökologie und Politik GmbH. Hamburg, Germany. 27 March 2000. Available from: https://ec.europa.eu/environment/pdf/waste/studies/elv/heavymetals1.pdf.
44. Kanari N, Pineau JL, Shallari S. End-of-life vehicle recycling in the European Union. JOM. 2003;55(8):15–9. DOI: 10.1007/s11837-003-0098-7.
45. Staudinger J, Keoleian GA. Management of End-of-Life Vehicles (ELVs) in the US. Ann Arbor (MI): Center for Sustainable Systems, University of Michigan. 2001. Available from: https://css.umich.edu/sites/default/files/css_doc/CSS01-01.pdf.
46. Luther N. (2005). Metal casting and molding processes. [Online]. Available from: www.castingsoruce.com/tech_art_metalcasting.asp.
47. Lampman S. Tuning up the metals in auto engines. Adv Mater Process. 1991;139:17–22.
48. March R. Charles Goodyear and the Strange Story of Rubber. Reader's Digest; 1958.
49. Poulikidou S. Identification of the Main Environmental Challenges in a Sustainability Perspective for the Automobile Industry. [Master's Thesis]. Gothenburg: Chalmers Tekniska Högskola; 2010. Available from: https://publications.lib.chalmers.se/records/fulltext/136380.pdf.
50. Castro MBG, Remmerswaal JAM, Reuter MA. Life cycle impact assessment of the average passenger vehicle in the Netherlands. Int J Life Cycle Assess. 2003;8(5):297–304. DOI: 10.1007/BF02978922.
51. Kuhndt M. Towards a Green Automobile: Life Cycle Management in EU and US. Lund: IIIEE Publications; 1997.

