Sustainable Manufacturing Practices: Evaluating the Environmental Benefits of Biodegradable Polymers and Recycled Metals

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Abstract. Among all industries looking for economic development and environmental responsibility, sustainable manufacturing has gained popularity worldwide. This study reviews how biodegradable polymers and recycled metals can be utilized to encourage sustainable manufacturing. In reality, biodegradable polymers are made from renewable materials such as starch or cellulose; hence they can be utilized rather than common plastics and they can avoid contamination caused by non-disposable polymers while at the same time improving resource productivity. Biodegradable polymers have found various applications in packaging, agriculture, and pharm sectors where they contribute towards sustainable product advancement through their potential to break down under certain conditions ensuring that no waste remains behind after usage. On the other hand, recycled metals are significant for accomplishing circularity in manufacturing systems and bringing down the natural impacts related to different stages of manufacturing processes. Recycled metals offer assistance to save natural resources, reduce energy utilization, and lower the amount of GHGs produced by mining and refining virgin ore. For sustainable manufacturing, this paper highlights participation as well as development and technology integration among other things. For instance; making eco-friendly materials may be one such activity while digitalizing production processes can be another great thought for improving environmental sustainability in the manufacturing sector. Moreover, this paper suggests a few areas that can foster greater natural protection amid production activities like switching over renewable sources of power supply for energy usage. These actions will

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not only guarantee economic development but also protect our environment because somehow they are interrelated to each other.

Keyword-: Biodegradable polymers, recycled metals, sustainability, innovation, manufacturing, digitalization, production process, energy consumption, greenhouse gas.

1 Introduction

The concept of Sustainable manufacturing covers each industrial action from the manufacturing plant to the client and all steps in between (i.e. resources and offerings related to the manufacturing chain). At present, production is related to all human endeavors; it offers products and facilities essential for human well-being, and security as well as maintaining human welfare. Since manufacturing processes provide basic needs for improving people's lives and worldwide economic improvement it should be considered from the sustainability perspective [1]. The utilization of biodegradable polymers and recycled metals indicates a new production strategy in manufacturing where environmental concerns are taken into consideration from the beginning of product design up until material acquisition and the production process. Biodegradable polymers also referred to as bio plastics offer solutions to worldwide increasing plastic contamination and natural damage. These types of materials are made from renewable sources such as starch, cellulose, or vegetable oils thus enabling them to break down naturally when in contact with the environment under the impact of microorganisms into safe substances [2]. Conventional plastics can remain for many years in landfills and oceans without breaking down, but usually, this is not the case with biodegradable polymers which are eco-friendly. Biodegradable polymers do more than just reduce plastic waste; they have the potential to lower down GHG emissions as well as protect limited natural resources. Also, the various applications of biodegradable plastics in different segments like packaging, agriculture, or pharma cultivate sustainable advancement and development [3].

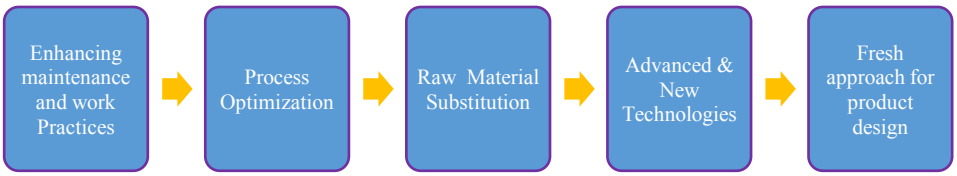

Fig. 1: The steps involved in implementing the sustainable manufacturing method

Essentially, there's a strategy of recycling metals that contributes altogether for sustainable production techniques by protecting resources and minimizing ecological impacts as shown in Fig.1. When aluminum, steel, and copper metals are recycled there's less need for mining virgin ores, energy is saved while at the same time, GHG emissions related to essential metal production are decreased. Amid recycling programs scrap metal is converted into important manufacturing input materials, improving resource productivity and circularity in fabric utilization [4]. The importance of reused metals is more than conserving resources but ensures the environment and prevents contamination. Clean air, water, and soil are part of what is contributed to through reusing metals as they prevent scrap metal from being disposed of in landfills and decrease the biological harms amid production processes. Besides, utilizing recycled metals in manufacturing makes a difference in accomplishing sustainable

development goals by bringing down reliance on nonrenewable materials while fostering a circular economy [5].

2 Biodegradable Polymers: Advantages and Applications

Biodegradable polymers also called Bioplastic are gaining popularity as sustainable choices for conventional polymers. These materials come from renewable sources like starch, cellulose, and vegetable oils, and have a number of natural benefits [6]. One primary advantage of bioplastics is that they can break down into secure substances by microorganisms naturally in the environment. Contrary to conventional polymers that may take centuries for decomposition and are harmful to the planet earth [7]. This means that plastic waste generation in landfills and oceans are on the dropping, and some other distinctions for a healthy environment conservation such as natural advantages and marine contamination management are made.

Furthermore, the making of biodegradable polymers produces less greenhouse gas emissions likened to the conventional plastics. Thus, the usage of renewable sources to reduce natural impacts cover the life span contributes greatly to reduce the effect on the climatic changes and supports the move towards a sustainable economy [8]. This point aligns with the growing global interest in reducing carbon footprints alongside developing eco-friendly approaches in various industries. There are numerous end-of-life methods for biodegradable polymers which can provide a wide variety of disposal alternatives. To mention, “Some forms might be engineered to decompose in central composting facilities, although others might deteriorate in garden compost heaps or average soils” [9]. Thus, it should has involved creating tailored solutions for particular businesses and environmental contexts from specific applications that boost sustainability and waste management. Biodegradable polymers can be used in various industries and replace conventional plastics with sustainable substitutes. Within the packaging section, it offers comparable mechanical and obstruction properties to conventional plastics, biodegradable polymers meet buyer demands for eco-friendly packaging arrangements, subsequently reducing plastic waste and minimizing natural impacts as presented in Table 1 [10].

Table 1: The physical characteristics and fire safety of several commercial polymers [14]

Property	Polylactic Acid	Polyethylene Terephthalate	Polyamide	Polypropylene
Density (kg/m³)	1240	1380	1140	920
Melting Temperature (K)	443.15 – 453.15	528.15 - 533.15	483.15 – 493.15	428.15 – 438.15
Glass Transition Temperature (K)	328.15 – 333.15	343.15 – 353.15	330.15 – 338.15	263.15
Time to Ignition (ms)	58000	46000	48000	42000
Smoke Generation (cm²/g)	630,000	3,940,000	1,950,000	1,420,000
Limiting Oxygen Index (%)	24	19	18	20
Peak Heat Release Rate (kW/m²)	425–450	625–640	575–590	495–510
Effective Heat of Combustion (kJ/g)	18	24	19	21

In the sustainability field biodegradable polymers also play an essential portion in empowering sustainable practices in farming. They are used in biodegradable plant pots, mulch, and seed coatings, among other purposes. In Biodegradable plastics, these agricultural applications not only decrease plastic waste but also improve soil quality by controlling weed improvement and this encourages sustainability [11]. Biodegradable polymers also support naturally acceptable agricultural operations by reducing the need for conventional plastic.

Biodegradable polymers are utilized broadly in medication for making biocompatible materials with different applications. They can be utilized to make biodegradable implants, drug conveyance systems as well as scaffolds for tissue building. These polymers offer amazing biocompatibility and don't require surgical removal after treatment thus expanding patients' comfort levels while decreasing healthcare costs which moreover drives forward medical innovation [12]. Biodegradable Polymers have discovered wider use since they can be degraded by natural processes into safe substances for example consumer goods and personal care items also shown in Table 1. This makes them appropriate for distinctive purposes ranging from single-use cutlery and food packaging through sanitary items like diapers to shopping bags which meet the requirements of individuals who need more ecologically friendly choices [13].

3 Recycled Metals in Manufacturing: Environmental Benefits

The utilization of recycled metals for manufacturing has become a sustainable activity with significant benefits. The industry can lower the natural effect of conventional metal extraction and contribute to preserving assets by utilizing recycled metals in different production forms. This paper analyses the different natural benefits of utilizing recycled metals in manufacturing operations [15]. Recycling metals gives an appealing solution for conserving assets and guaranteeing natural sustainability. Unlike creating new metals that include mining and processing recycling metals are made from scrap metal and waste metals. Manufacturers can re-use them which makes a huge difference since it diminishes the requirement for virgin ore extraction subsequently conserving natural assets and cutting down on ecological problems caused by mining [16].

Scrap metal makes up a huge portion of municipal solid waste and, whenever this waste is disposed of improperly, it contaminates the environment and destroys living space. Recycling programs convert such scrap into important manufacturing feedstock subsequently diminishing the volume bound for burning or burial while also reducing associated natural impacts [17]. When we talk about conserving resources, it has an advantage that if recycled metals are used in production processes it not only saves huge amounts of energy but cuts down emissions significantly. Manufacturing virgin materials out of mined ores demands lots of energy which leads to GHG emissions levels during extraction/refining stages. On the other hand, recycling only needs less amount of power with low GHG emissions since this approach of recycling eliminates these high-energy procedures as shown in Table 2 [18].

Table 2: Environmental advantages of utilizing recycled metals in manufacturing

Environmental Benefit	Description	Example
Resource Conservation	Repurposing scrap metal reduces the need for virgin ore extraction, conserving natural resources.	Recycling discarded automobiles into steel reduces the demand for iron ore mining.
Waste Diversion	Recycling transforms scrap metal into new materials, reducing waste sent to landfills.	Recycling old appliances diverts metal waste from ending up in landfill sites.
Energy Savings	Recycling metals consumes less energy than primary production, reducing emissions.	Recycling aluminum saves energy compared to producing it from raw materials.
Emissions Reduction	Using recycled metals lowers emissions from metal production processes.	Using recycled steel reduces carbon emissions compared to primary steel production.
Pollution Mitigation	Recycling metals minimizes pollution from extraction and processing, improving environmental quality.	Recycling reduces pollution from mining and processing, improving air, water, and soil quality.
Habitat Preservation	Recycling reduces the need for new mining, preserving ecosystems and biodiversity.	Decreasing demand for new metal extraction protects habitats and ecological balance.

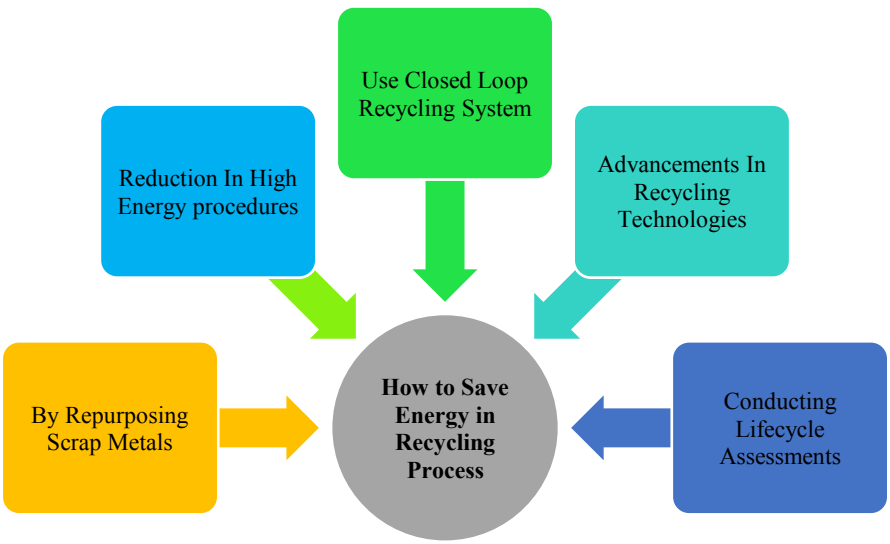

Fig. 2: How recycling metals during production promotes sustainability and energy efficiency

For example, as shown in Fig.2 recycling aluminum employs a part of the energy required to produce essential aluminum from bauxite minerals. A considerable amount of energy can be

saved by producers through the utilization of recycled aluminum and lower carbon footprint [19]. Additionally, steel recycling and other metals have been known for saving huge amounts of energy and reductions in emissions, and it also serves global efforts to reduce ecological imbalance caused by pollution and climate change [20]. Additionally, when we utilize recycled metals amid production it diminishes contaminations caused by extracting metals from their ores and handling them into usable shapes which usually includes spreading contaminants into air or water other than contaminating soils with heavy chemicals it also destroys different environments; so if we promote metal recyclability we can prevent negative environmental effects and improves the quality of natural resources (air, water, soil, etc.) [21, 22].

4 Future Directions and Opportunities in Sustainable Manufacturing

Globally, industries are presently highly curious about sustainable manufacturing which has been quickened by three things; the disturbing increment of natural issues, request for eco-friendly goods, and administrative pressures as well [23]. Future directions as well as opportunities for sustainable manufacturing are anticipated to convert the industrial segment as companies attempt to diminish their environmental impact while embracing ecologically beneficial approaches as shown in Table 3. This part analyzes new inclinations, challenges faced, and chances available in sustainable manufacturing that can foster innovation and development in completely different ranges [24]. One region with a lot of promise for creative thoughts when it comes to sustainable production is making materials that are environmentally friendly or maybe those items that can be referred to as such. Collaborations between diverse segments may offer various events for working together toward the creation and commercialization of these materials [25].

Real-time supervision coupled with prescriptive analytics fosters preventive upkeep which in turn minimizes downtime while maximizing asset allocation [26]. In addition, digital copies alongside simulation devices encourage producers to create models as well as optimize their production forms towards sustainability in this manner identifying zones that will require waste disposal, energy saving, or emissions reduction. Sustainable development inside the manufacturing sector will proceed to develop alongside improvement in digitalization thus leading to productivity gains and natural performance changes [27].

Renewable energy is one of the major portions of sustainable manufacturing because it permits companies to decarbonize their operations as well as stop depending so intensely on fossil fuels. Conventional energy sources are being replaced with solar energy, wind, and hydroelectricity which are cleaner and can be utilized many times for production processes [28]. Furthermore, modern techniques of storing supply energy let businesses save up additional energy and then utilize it when required most; this lowers the price and carbon emissions. Investing in renewable energy infrastructure while also offering incentives and supportive approaches may speed up adoption rates of sustainable manufacturing in the industry [29] Partnerships with suppliers of renewable energy and creative funding methods who offer ways to finance projects may be necessary if we need these changes to happen rapidly and this can benefit environmentally and economically [30].

Table 3: Key Opportunities and Trends in Sustainable Manufacturing

Opportunities & Trends	Description	Key Initiatives/Actions	Reference
Development of Sustainable Materials and Eco-friendly Products	Advances in product design and materials research to produce ecologically friendly substitutes.	Partnership for material development and alliances across sectors	[25]
Integration of Digital Technologies and Industry 4.0 Principles	Optimizing manufacturing processes for sustainability through the use of digital twins, AI, IoT, data analytics, and simulation tools.	Production process optimization, digital twin modeling, predictive analytics, and real-time monitoring	[26], [27]
Transition to Renewable Energy Sources	Adoption of hydropower, solar, and wind energy to lessen dependency on fossil fuels and decarbonize operations.	Infrastructure investment for renewable energy, policy support, and cooperation with renewable energy suppliers	[28], [29]
Ensuring Supply Chain Resilience and Transparency	Integrating blockchain technology and teamwork to improve sustainability, ethical standards, and traceability across the supply chain.	Blockchain for supplier cooperation, industry groups, NGOs, and supply chain transparency	[31], [32]

To progress sustainability in manufacturing, it is critical to make the supply chain more strong and straightforward. Businesses are getting to be more mindful of their supply chains as they try to find out risks and challenges; increase traceability as well as enhance natural or social performance [31]. The innovation of blockchain has potential uses in guaranteeing secure supply chain administration systems that are moreover straightforward where companies can follow up on where their materials were sourced from and if these materials meet sustainable guidelines [32]. Supplier collaboration, industry associations' engagement with NGOs, etc., may help to promote the adoption of sustainable sourcing actions while at the same time guaranteeing ethical labor guidelines across all levels of the supply chain. Customers, investors, and other stakeholders must trust manufacturers so that they can succeed in a competitive market [33].

5 Conclusion

In short it can be said that the utilization of biodegradable polymers and recycled metals in manufacturing may be a major move towards sustainable manufacturing. Sustainable manufacturing looks forward to more collaboration, advancement, and integration of technology. This will be accomplished by coming up with eco-friendly substances, digitizing production, adopting renewable sources of energy as well as supply chain flexibility enhancement among other measures pointed at advancing sustainability objectives.

- Biodegradable polymers can solve the issue of plastic contamination and consumption of resources, though recycled metals reduce a natural effect from manufacturing operations. These sustainable alternatives offer assistance to decrease waste sent to landfills and save nature, due to which they are regarded as having the minimal possible impact on the environment.
- Talking about resource conservation, it is expanding through biodegradable polymers and recycled metals, reducing the need for raw materials. Generally in industries, biodegradable plastics are made from renewable raw materials while recycling includes reused scrap metal, and all this creating a resource-efficient and material-made circular economy.
- On the behalf of energy productivity, the application of biodegradable polymers or recycled metal in traditional production processes helps to improve it. These sustainable choices of materials help to lower energy usage during production in industries, and reducing GHG as a result that are accountable for climate alterations and other forms of ecological damages.

References

1. Abubakr, Mohamed, Adel T. Abbas, Italo Tomaz, Mahmoud S. Soliman, Monis Luqman, and Hussien Hegab. "Sustainable and smart manufacturing: an integrated approach." Sustainability 12, 6 (2020): 2280.
2. Rai, Pawankumar, Srishti Mehrotra, Smriti Priya, Edgard Gnansounou, and Sandeep K. Sharma. "Recent advances in the sustainable design and applications of biodegradable polymers." Bioresource technology 325 (2021): 124739.
3. Dilkes-Hoffman, L. S., S. Pratt, P. A. Lant, and B. Laycock. "The role of biodegradable plastic in solving plastic solid waste accumulation." In Plastics to energy, 469-505. William Andrew Publishing, 2019.
4. Gorman, Miranda R., David A. Dzombak, and Chad Frischmann. "Potential global GHG emissions reduction from increased adoption of metals recycling." Resources, Conservation and Recycling 184 (2022): 106424.
5. Pimenov, Danil Yu, Mozammel Mia, Munish K. Gupta, Álisson R. Machado, Giuseppe Pintaude, Deepak Rajendra Unune, Navneet Khanna et al. "Resource saving by optimization and machining environments for sustainable manufacturing: A review and future prospects." Renewable and Sustainable Energy Reviews 166 (2022): 112660.
6. Makhijani, Komal, Ramkesto Kumar, and Sanjay K. Sharma. "Biodegradability of blended polymers: A comparison of various properties." Critical Reviews in Environmental Science and Technology 45, 16 (2015): 1801-1825.
7. Paul, Sayantani, Bibaswan Sen, Sangita Das, Sk Jahir Abbas, Surya Narayan Pradhan, Kakali Sen, and Sk Imran Ali. "Incarnation of bioplastics: recuperation of plastic pollution." International Journal of Environmental Analytical Chemistry 103, 19 (2023): 8217-8240.
8. Satrovic, Elma, Ahmet Cetindas, Ibrahim Akben, and Sadeq Damrah. "Do natural resource dependence, economic growth and transport energy consumption accelerate ecological footprint in the most innovative countries? The moderating role of technological innovation." Gondwana Research 127 (2024): 116-130.
9. Wahab, Salman, Muhammad Imran, Bilal Ahmed, Syed Rahim, and Taimoor Hassan. "Navigating environmental concerns: Unveiling the role of economic growth, trade, resources and institutional quality on greenhouse gas emissions in OECD countries." Journal of Cleaner Production 434 (2024): 139851.
10. Azeem, Iqra, Binish Ashfaq, Muhammad Sohail, and Basit Yameen. "Polymer Surface Engineering in the Food Packaging Industry." In Nanoscale Engineering of

Biomaterials: Properties and Applications, 457-485. Singapore: Springer Nature Singapore, 2022.
11. Somanathan, Harshitha, Ramaraj Sathasivam, Salini Sivaram, Sivaniraji Mariappan Kumaresan, Meenakshi Sundaram Muthuraman, and Sang Un Park. "An update on polyethylene and biodegradable plastic mulch films and their impact on the environment." Chemosphere 307 (2022): 135839.
12. Sharma, Bhasha, Shreya Sharma, and Purnima Jain. "Leveraging advances in chemistry to design biodegradable polymeric implants using chitosan and other biomaterials." International journal of biological macromolecules 169 (2021): 414-427.
13. Haider, Tobias P., Carolin Völker, Johanna Kramm, Katharina Landfester, and Frederik R. Wurm. "Plastics of the future? The impact of biodegradable polymers on the environment and on society." Angewandte Chemie International Edition 58, 1 (2019): 50-62.
14. Maqsood, Muhammad, and Gunnar Seide. "Biodegradable flame retardants for biodegradable polymer." Biomolecules 10, 7 (2020): 1038.
15. Jisha, P. K., Prashantha, S. C., & Nagabhushana, H. (2017). Luminescent properties of Tb doped gadolinium aluminate nanophosphors for display and forensic applications. Journal of Science: Advanced Materials and Devices, 2(4), 437-444.
16. Alrobei, H., Prashanth, M. K., Manjunatha, C. R., Kumar, C. P., Chitrabanu, C. P., Shivaramu, P. D., ... & Raghu, M. S. (2021). Adsorption of anionic dye on eco-friendly synthesised reduced graphene oxide anchored with lanthanum aluminate: Isotherms, kinetics and statistical error analysis. Ceramics International, 47(7), 10322-10331.
17. Kulandaivel, D., Rahamathullah, I. G., Sathiyagnanam, A. P., Gopal, K., & Damodharan, D. (2020). Effect of retarded injection timing and EGR on performance, combustion and emission characteristics of a CRDi diesel engine fueled with WHDPE oil/diesel blends. Fuel, 278, 118304.
18. Hora, S. K., Poongodan, R., De Prado, R. P., Wozniak, M., & Divakarachari, P. B. (2021). Long short-term memory network-based metaheuristic for effective electric energy consumption prediction. Applied Sciences, 11(23), 11263.
19. Raj, T. V., Hoskeri, P. A., Muralidhara, H. B., Manjunatha, C. R., Kumar, K. Y., & Raghu, M. S. (2020). Facile synthesis of perovskite lanthanum aluminate and its green reduced graphene oxide composite for high performance supercapacitors. Journal of Electroanalytical Chemistry, 858, 113830.
20. Wu, Junnian, Ruiqi Wang, Guangying Pu, and Hang Qi. "Integrated assessment of exergy, energy and carbon dioxide emissions in an iron and steel industrial network." Applied Energy 183 (2016): 430-444.
21. Agboola, Oluranti, Damilola E. Babatunde, Ojo Sunday Isaac Fayomi, Emmanuel Rotimi Sadiku, Patricia Popoola, Lucey Moropeng, Abdulrazaq Yahaya, and Onose Angela Mamudu. "A review on the impact of mining operation: Monitoring, assessment and management." Results in Engineering 8 (2020): 100181.
22. Rajendran, Saravanan, T. A. K. Priya, Kuan Shiong Khoo, Tuan KA Hoang, Hui-Suan Ng, Heli Siti Halimatul Munawaroh, Ceren Karaman, Yasin Orooji, and Pau Loke Show. "A critical review on various remediation approaches for heavy metal contaminants removal from contaminated soils." Chemosphere 287 (2022): 132369.
23. Khan, Syed Abdul Rehman, Zhang Yu, Arshian Sharif, and Hêriş Golpîra. "Determinants of economic growth and environmental sustainability in South Asian Association for Regional Cooperation: evidence from panel ARDL." Environmental Science and Pollution Research 27 (2020): 45675-45687.
24. Javaid, Mohd, Abid Haleem, Ravi Pratap Singh, Shahbaz Khan, and Rajiv Suman. "Sustainability 4.0 and its applications in the field of manufacturing." Internet of Things and Cyber-Physical Systems 2 (2022): 82-90.

25. Song, Wenhao, and Hongyan Yu. "Green innovation strategy and green innovation: The roles of green creativity and green organizational identity." Corporate Social Responsibility and Environmental Management 25, 2 (2018): 135-150.
26. George, A. Shaji. "Securing the future of finance: how AI, Blockchain, and machine learning safeguard emerging Neobank technology against evolving cyber threats." Partners Universal Innovative Research Publication 1, 1 (2023): 54-66.
27. Naresh, M., & Munaswamy, P. (2019). Smart agriculture system using IoT technology. International journal of recent technology and engineering, 7(5), 98-102.
28. Ramprasad, P., Basavapoornima, C., Depuru, S. R., & Jayasankar, C. K. (2022). Spectral investigations of Nd3+: Ba (PO3) 2+ La2O3 glasses for infrared laser gain media applications. Optical Materials, 129, 112482.
29. Goud, J. S., Srilatha, P., Kumar, R. V., Kumar, K. T., Khan, U., Raizah, Z., ... & Galal, A. M. (2022). Role of ternary hybrid nanofluid in the thermal distribution of a dovetail fin with the internal generation of heat. Case Studies in Thermal Engineering, 35, 102113.
30. Yue, L., Jayapal, M., Cheng, X., Zhang, T., Chen, J., Ma, X., ... & Zhang, W. (2020). Highly dispersed ultra-small nano Sn-SnSb nanoparticles anchored on N-doped graphene sheets as high performance anode for sodium ion batteries. Applied Surface Science, 512, 145686.
31. Indira, D. N. V. S. L. S., Ganiya, R. K., Babu, P. A., Xavier, A. J., Kavisankar, L., Hemalatha, S., ... & Yeshitla, A. (2022). Improved artificial neural network with state order dataset estimation for brain cancer cell diagnosis. BioMed Research International, 2022.
32. Berdik, David, Safa Otoum, Nikolas Schmidt, Dylan Porter, and Yaser Jararweh. "A survey on blockchain for information systems management and security." Information Processing & Management 58, no. 1 (2021): 102397.
33. Mani, Venkatesh, Angappa Gunasekaran, and Catarina Delgado. "Enhancing supply chain performance through supplié social sustainability: An emerging economy perspective." International Journal of Production Economics 195 (2018): 259-272.