Polystyrene Waste Covert into Adhesives as a Sustainable Waste Management Solution

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ABSTRACT

Adhesives, made from both natural and synthetic polymeric materials, can permanently join surfaces through mechanical force or work. This research project aims to address environmental problems caused by polystyrene waste by converting it into environmentally friendly adhesive materials. In this study, the best solvent is determined by using three types of solvents: toluene, kerosene, and a mixture of toluene and kerosene. A mixture consisting of 30 ml of toluene, 30 ml of kerosene, and 30 ml of the toluene-kerosene mixture (with proportions of 15 ml toluene and 15 ml kerosene) are prepared. 10g of Styrofoam is utilized in the process. About 3ml of adhesive, prepared using the above methods, this is applied to bond two cardboard pieces size of 10cm*5cm. Three such samples are created, and the strength is measured. The adhesive strength obtained with toluene is measured at 0.1 MPa, with kerosene at 0.4 MPa, and with the mixture at 2.9 MPa. From the data, it can be inferred that the best solvent for producing adhesive is the toluene-kerosene mixture. 3ml of the prepared adhesive (the toluene-kerosene mixture) is used to bond the cardboard, plastic, and aluminum pieces, and the samples are left for a day to measure the strength. The measured strengths are 2.0 MPa for cardboard, 1.8 MPa for plastic, and 68.2 MPa for aluminum. Based on the data, aluminum demonstrates the highest strength. Due to the extended drying time required for aluminum, cardboard is utilized to quickly measure the material with the highest strength. 3ml of adhesive is applied to bond two 10cm*5cm cardboard pieces, creating two samples. The strength of one sample is measured after one hour, while the other sample's strength is measured after two hours. It is observed that the strength measures 2.0 MPa after one hour and increases to 2.4 MPa after two hours, indicating that strength increases with time.

Keywords: Adhesives, Polystyrene waste, Sustainable solution, Strength

INTRODUCTION

Waste management is a very critical and burning problem in the current world [1]. With the industrial revolution, a lot of companies are generating significant amounts of waste. This waste can be mainly classified into two groups biodegradable and non-biodegradable waste [2] [3]. Biodegradable waste is not a big problem when compare with the non-biodegradable wastes [4] [5]. Another classification is hazardous waste and non-hazardous waste. The waste categorized as hazardous waste is more dangerous than the non-hazardous waste [6] [7]. A sustainable waste management solution is needed for hazardous waste [8].

Polyester waste is considered as non-biodegradable and hazardous waste. It will take a long time to vanish from the earth and it releases environmental pollutants for a long period of time. Due to the hazardous nature of this material, it creates a lot of health and environmental problems [9] [10]. Due to its nonbiodegradability, this material contributes to microplastic contamination. Limited disposal options are available for this polystyrene waste then which creates huge environmental effects and this will help to resource depletion because it can be used for fossil fuels [11].

Polystyrene has special characteristics and properties such as transparency, lightweight weight, and translucency [12]. This material is very popular among industries and it is used as the packaging material and disposable

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container for so many industrial applications [13]. At room temperature, the rigid and brittle nature of this material will help for some special industrial applications. Due to the thermal resistance property of this material, it can be used as an insulation material for some applications [14]. The electric conductivity of this polystyrene material is very low, so it is used as an insulation material for some electrical applications [15]. Due to the user-friendly properties of this material, demand for this material has increased and another thing is waste generation rate of this polystyrene waste also has increased [16].

Annually 13 million metric tons of polyester waste are generated in the world [17] [18], it has huge potential to damage the environment as well as human health. The highest waste-generating countries are China, the United States, India, Indonesia, and the European Union [19] [20]. Due to industrial activities developed countries are generating more polystyrene waste [21]. Limited disposal facilities are available for this polystyrene waste as a result of it this waste has polluted landfill sites, oceans, and waterways, damaging wildlife and ecosystems in developed countries [22]. With time this waste breaks down into micro-level particles then it creates more health effects and greenhouse gas emissions. While producing products or incinerating polystyrene waste it releases greenhouse gases and finally, it affects climate change [23]. Another thing is when this waste is stored it will consume a huge area due to the low bulk density of these materials. In the industry, this waste consumes more space in the waste yard than the other waste materials [24].

In Sri Lanka, Industries stabilized in BOI zones are doing bulk-wise industrial-level manufacturing activities. They release more polystyrene waste as the output of their production process. In Sri Lanka more than 400 companies are producing polystyrene waste, they use polystyrene materials for their operations as packaging materials, use for insulation activities, and produce disposal cups and plates. This polystyrene waste generation is showing a rapidly growing trend in Sri Lanka. In 2018 over 20,000 metric tons of polystyrene waste [25]. The reasons for these rapid increments are demand for polystyrene products has increased, production costs are also very low, and government support. However, companies have to face big challenges due to this waste environmental and health risks, waste management and storing problems, fire risks, and other social problems. Since the bulk density of this material is very low, it will consume more space in waste-storing facilities in the industry [26].

This study mainly focused on providing sustainable waste management solutions for polystyrene waste. In this case, polystyrene waste is coveted into another usable product mixing with different types of solvents. When polystyrene is mixed with the chemical solvent it converts into liquid adhesive. It can be used for different types of applications. The properties of this adhesive will vary based on the solvent used to mix with polystyrene waste. Due to this conversion, more advantages can be achieved. It will be a good waste management solution for polystyrene waste and due to this conversion solid waste can be converted into liquid materials as a result of it more space in the waste storing yard can be saved. If the industry can do this conversion by producing adhesive inside their company, they can earn extra profit by selling these products to the local market. Another thing is by educating village people regarding this conversion technology new job opportunities can be created inside the country. A lot of environmental problems can be solved through this alternative waste management solution [27]. An easy way to comply with the conference paper formatting requirements is to use this document as a template and simply type your text into it.

METHODOLOGY

Generating Styrofoam in the industry is causing massive problems to the environment. Present, the quantity of generated Styrofoam is getting high level. It is used as a material for packaging, insulation, and food containers in large quantities. Its human and environmental cost is high because it doesn't biodegrade, hazardous to wildlife. This enters the natural environment and animals often mistake it for food. Styrofoam with low weight and high volume are hard to store. It needs a large space to store [28].

The Styrofoam waste in the industry poses significant environmental challenges. This study aims to address this issue by exploring the production of an adhesive using different combinations of Styrofoam with Kerosene and Toluene. The adhesive's effectiveness in bonding various materials will be evaluated to determine its potential as a sustainable solution for reducing Styrofoam waste [29].

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Three types of samples were prepared for this study to produce adhesive (Table 1)

TABLE 1: Sample Mixing Quantities

Sample	Polystyrene waste (g)	Toluene (ml)	Kerosene (ml)
Sample 01	10 g	30 ml	0
Sample 02	10 g	0	30 ml
Sample 03	10 g	15 ml	15 ml

According to the above-mentioned ratios, Samples 01,02 and 03 were prepared. Then measured the adhesive strength by applying this adhesive to cardboard materials and allowing them to dry at constant time period.

There were three tests Best Solvent Test, Material Test, and Time Test. After making this adhesive, first of all, 6 pieces of 10*5cm cardboard were made 3ml of adhesive was added and 3 samples were made.

Some adhesives are suitable for specific materials to measure and different types of materials were used like cardboard, Aluminium, and plastic. Three substrate materials cardboard, aluminium, and plastic are selected for testing. Then took 3ml of adhesive made from that mix (Styrofoam 10g + Kerosene15ml + Toluene 15ml) and pasted these materials called cardboard, plastic, and aluminium from the sizes of 10*5cm and left it for a day to see which material had the highest strength. then measure the strength of each sample.

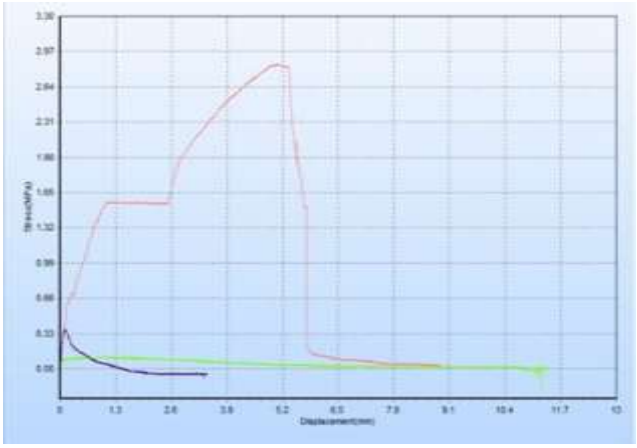
Another experiment was conducted to measure whether the adhesive strength varies based on time. For that adhesives were applied in the same materials and the three samples of the same material were prepared and those samples kept for one hour, two hours, and one day to dry for different time periods and measure the strength of those samples.

In this experiment, as the strength, tensile strength was measured by using a universal tensile strength testing machine. Tensile Electronic Universal Testing Machine is a small, benchtop machine with a capacity of 100 kN, capable of applying up to 100,000 Newtons of force. The machine features microcomputer control for precise test parameters, a digital display showing force, displacement, and stress of the specimen, various Testin modes, and data acquisition for creating stress-strain curves [29].

RESULTS AND DISCUSSION

Select the best solution as an adhesive

For this experiment sample 01, sample 02 and sample 03 were created and after measuring their tensile strength below mentioned results were given(Fig1).



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Green colour line for sample 01, Blue colour line for sample 02, and red colour line for sample 03. Bar chart of these results is given below (Table 2)

TABLE 2: Tensile strength and displacement of three samples

Solvent	Stress (Mpa)	Displacement (mm)
Toluene(S1)	0.1	1.1
kerosene(S2)	0.4	0.1
Mixture(S3)	2.9	5.1

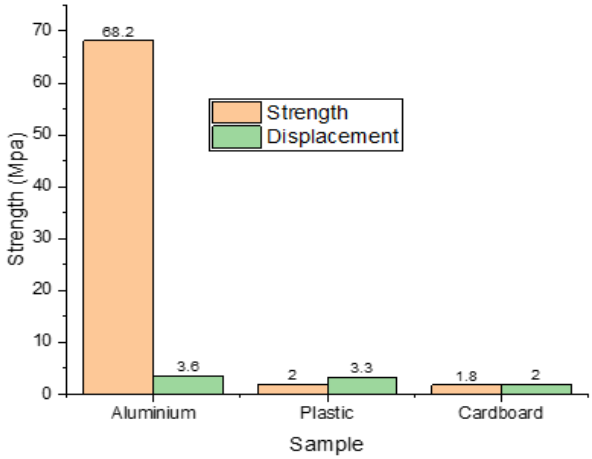

Fig 1: Tensile strength of different samples

According to the above results highest tensile strength is shown in sample 03, That's means if we can prepare an adhesive using 10g of polystyrene waste mixed with 15g of toluene and 15g of kerosene.

The other two sample strengths are below the sample 03 value. Sample 03 shows significantly higher strength when compared with the other two samples.

By using this high perform adhesive (Sample 03) other two experiments were done. Next experiment was done to find out the best material that this adhesive can use as the glue. For this experiment three types of materials were used those are Aluminium, Plastic, and cardboard. After applying adhesive, the tensile strength of those materials was measured. Those results are as follows (Fig 3).

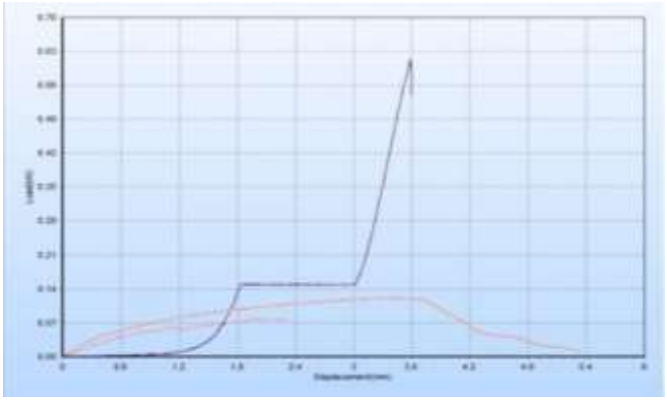

Fig 3: Strength variations base on the material types

In this graph blue colour line shows the strength variation of aluminium materials, the orange colour line shows the strength variation of plastic and the red colour line shows given strength variation of cardboard material. The

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bar chart and the results table of this experiment are given below (Table 3)

TABLE 3: Strength and displacement base on the material type

Material	Stress (Mpa)	Displacement (mm)
Aluminium	68.2	3.6
Plastic	2	3.3
Cardboard	1.8	2

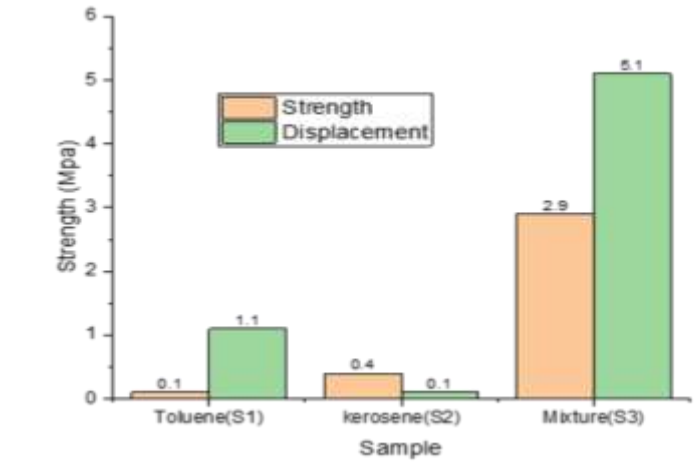

Fig 2: Strength variation base on the material type

When we study the above results, highest strength is provided when we apply this adhesive to in aluminium sheet. Then among these three materials, this adhesive is more suitable to apply for aluminium related repairing activities or relevant applications.

Another experiment was conducted to measure how this strength will vary with the drying time. After applying adhesive to a material some time, we have to keep that material to attach each parts properly. Here, two cardboard samples of 10*5cm size were used and 3ml of the best adhesive was used to paste to measure the best time and the stress. Styrofoam (10g) + Toluene (15ml) + Kerosene (15ml) mix was used as the adhesive. Then one sample allowed one hour and another one allowed for two hours to measure the best time.

For one sample of cardboard size, 10*5cm was taken and 3ml of the best adhesive was taken and left for an hour. Styrofoam (10g) + Toluene (15ml) + Kerosene (15ml) mix was used as the adhesive. After one hour the stress was measured(fig5). Maximum stress was 2.0Mpa. The y-axis shows the stress and X-axis shows the Displacement.

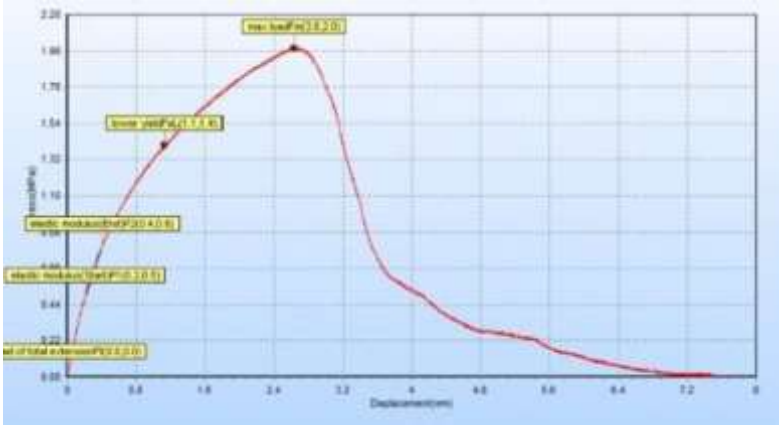

Fig 5: Strength vs displacement, sample after keeping 01 hour

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Material	Stress (Mpa)	Displacement (mm)
Aluminium	68.2	3.6
Plastic	2	3.3
Cardboard	1.8	2

Another sample of cardboard size 10*5cm was taken and 3ml of the best adhesive was taken and left for two hours. Styrofoam (10g) + Toluene (15ml) + Kerosene (15ml) mix was used as the adhesive. After two hours the stress was measured. Maximum stress was 2.4Mpa. The stress of cardboard increases with time.

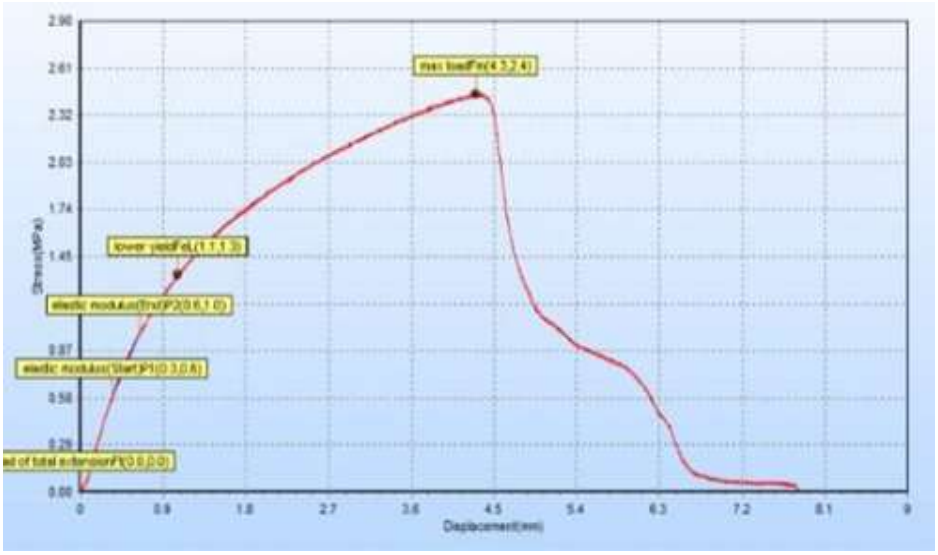

Fig 3:Strength vs displacement, sample after keeping 02 hours

TABLE 4: Strength variation according to the time

Time	Stress (Mpa)	Displacement (mm)
1hour	2	2.6
2hour	2.4	4.3

According to these results (Table 4), the tensile strength has increased with time. After applying this adhesive if we can keep samples for more than one hour it will properly fix and then with time, this bonding strength will increase.

CONCLUSION

Polystyrene waste is hazardous waste and it has created significant environmental effects and it is a burning problem for the industry. Main thing is due to its low bulk density it will take huge space from the waste storage yard. Another thing is it will increase the transportation cost. Polystyrene waste is creating environmental and economic problems.

In this study, polystyrene waste was converted into liquid adhesive mixed with the chemical solvent. According to this experiment, polystyrene volume can be reduced by converting it into liquid form. The best adhesive mixture can be obtained by mixing 10g of polystyrene waste with 15g of toluene and 15g of kerosene. Then according to the second experimental result, this adhesive is more suitable for applying Aluminium materials. After applying this adhesive for more than one hour it needed to be kept till drying.

This will be a good environmental solution for polystyrene waste. Another thing is If we can promote this production process among the village people they can start their own businesses. It will create more job opportunities for the people. This research can be improved in the future by doing experiments to improve the quality of this adhesive. Then quality products can be introduced to society. Then it will help to solve the huge environmental problems in the society.

REFERENCES

1. A. P. N. M. M. S. A. Y. &. F. G. Gauri Thakur, "A significant exploration on meta-heuristic based approaches for optimization in the waste management route problems," Scientific Reports, vol. 14, no. https://doi.org/10.1038/s41598-024-64133-1, p. 14853, 2024.
2. D. A. F. J. G. Dr. Waneene Dorsey, "Biodegradable and Non-biodegradable Waste," in Environmental Science, LOUIS, The Louisiana Library Network, 2024.
3. I. d. S. ·. A. Woodhouse1, "Environmental impact of biodegradable and non biodegradable agricultural mulch film: A case study for Nordic conditions," The International Journal of Life Cycle Assessment, vol. 29, no. https://doi.org/10.1007/s11367-023-02253-y, p. 275–290, 2024.
4. W. E. H. H. Amarasinghe AMPC*, "Analysis of Ethanol Production Potential from Different Types of Fruit Waste," INTERNATIONAL JOURNAL OF RESEARCH AND INNOVATION IN APPLIED SCIENCE (IJRIAS), vol. 9, no. ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS, pp. 275-284, 2024.
5. A. A. S. E. W. R. Wijesekara ERJMDDP, "Comparative Analysis of Bioethanol Production Capacities from Different Chemically Pretreated Rice Straws," INTERNATIONAL JOURNAL OF RESEARCH AND INNOVATION IN APPLIED SCIENCE (IJRIAS), vol. 9, no. ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS, pp. 435-445, 2024.
6. P. A. A. I. V. V. K. R. K. Dasith Wijesekara, "Energy, Exergy, and Environmental Impact Analysis and Optimization of Coal–Biomass Combustion Combined Cycle CHP Systems," Sustainability, vol. 17, no. 6, p. 2363, 2024.
7. J. K. S. Boris Novarlić1*, "Natural Hazards and Their Environmental Impact: Flood Risks in the Systemic Management of Non-Hazardous Municipal Waste," Opportunities and Challenges in Sustainability, vol. 3, no. https://doi.org/10.56578/ocs030203, pp. 96-107, 2024.
8. P. G. a. M. N. Krishnaswamy Kanagamani, Hazardous Waste Management, 10.5772/intechopen.87467, 2020.
9. F. L. R. a. d. Abdul Halim a, "Expanded polystyrene waste valorization as a hydrophobic coating II:," South African Journal of Chemical Engineering, vol. 49, no. https://doi.org/10.1016/j.sajce.2024.05.001, pp. 114-121, 2024.
10. R. D. B. M. E. B.-Z. W. H. N. V. L. Michiel Rita Kol, "Increasing the Dissolution Rate of Polystyrene Waste in Solvent-Based Recycling," ACS Sustainable Chemistry & Engineering, vol. 12, no. https://doi.org/10.1021/acssuschemeng.3c08154?urlappend=%3Fref%3DPDF&jav=VoR&rel=cite-as, pp. 4619-4630, 2024.
11. J. Korkiamäki, "Recycling of Polystyrene in Suspension Polymerization Process," Laboratory of Polymer Technology Faculty of Science and Engineering, June 2020.
12. F. M. M. L. A. K. A. G. D. B. G. V. D. H. F. K.-H. Santiago Franco Corredor, "A Polystyrene Photoresin for Direct Lithography of Microfluidic Chips," Advance materials technology , vol. 7, no. DOI: 10.1002/admt.202200084, pp. 1-6, 2022.
13. †. ,. G. W. †. Y. W. ,. N. J. a. K. N. Hongfu Li *, "Functionalization of Carbon Nanotubes in Polystyrene and Properties of Their Composites: A Review," polymers, vol. 16, no. doi.org/10.3390/polym16060770, p. 770., 2024.
14. Y. Y. a. M. W. Woo, "Transitioning of petroleum-based plastic food packaging to sustainable bio-based alternatives," Sustainable Food Technology, vol. 2, no. DOI: 10.1039/d4fb00028e, p. 548–566, 2024.
15. R. Brooks, A. N. C. C. L. A. Tiffany Coppock and M. Dillon, "Considerations for Specifying Rigid, Cellular Polystyrene Insulations in Various Applications," IIBEC Interface, 2024.
16. I. M. Maafa, "Pyrolysis of Polystyrene Waste: A Review," Polymers, no.

https://doi.org/10.3390/polym13020225, p. 2 of 30, 2021.
17. S. C. J. D. R. G. Jesse Daystar, "The global apparel industry: a signicant, yet overlooked source of plastic leakage," Research square, no. https://doi.org/10.1038/s41467-024-49441-4, 2023.
18. J. D. S. C. J. D. R. G. S. P. S. U. S. R. A. V. J. Anna Kounina, "The global apparel industry is a significant yet overlooked source of plastic leakage," Nature Communications, no. 10.1038/s41467-024-49441-4, 2024.
19. V. P.-G. a. J. M. R.-Á. Arantxa M. Gonzalez-Aguilar, "A Thermo-Catalytic Pyrolysis of Polystyrene Waste Review: A Systematic, Statistical, and Bibliometric Approach," polymers, vol. 15, no. https://doi.org/10.3390/polym15061582, p. 1582, 2023.
20. 2. ·. X. D. Z. J. Jianqiang Zhu1, "Microplastics in polystyrene made food containers from China: abundance, shape, size, and human intake," Environmental Science and Pollution Research, vol. 30, no. https://doi.org/10.1007/s11356-022-25093-z, p. 40084–40093, 2023.
21. 2. M. B. F. X. Y. W. P. S. C. S S Yang1, "Progresses in Polystyrene Biodegradation and Prospects for Solutions to Plastic Waste Pollution," 8th International Conference on Future Environment and Energy (ICFEE 2018), no. doi :10.1088/1755-1315/150/1/012005, 2018.
22. N. N. J. B. B. A. H. S. O. N. F. A. B. 2, "Unveiling the noxious effect of polystyrene microplastics in aquatic ecosystems and their toxicological behavior on fishes and microalgae," Front. Toxicol, no. https://doi.org/10.3389/ftox.2023.1135081, 2023.
23. K. C. a. Y.-C. J. Youngsun Kwon, "Greenhouse Gas Emissions from Incineration of Municipal Solid Waste in Seoul, South Korea," energies, vol. 16, no. https://doi.org/10.3390/en16124791, p. 4791, 2023.
24. J. Y. Q. T. X. J. L. a. J. Y. C. L. Celine W. S. Yeung, "Polyolefins and Polystyrene as Chemical Resources for a Sustainable Future: Challenges, Advances, and Prospects," American Chemical Society, no. https://doi.org/10.1021/acsmaterialslett.1c00490?urlappend=%3Fref%3DPDF&jav=VoR&rel=cite-as, 2021.
25. R. T. K. A. A. K. K. S. M. W. B. F. A. Basnayake, "Sustainable Waste Management Challenges in Sri Lanka," DOI: 10.4018/978-1-7998-0198-6.ch015, 2019.
26. K. A. Conlon, "Waste Management in the Global South: an Inquiry on the Patterns of Plastic and Waste Material Flows in Colombo, Sri Lanka," Portland State University, 2020.
27. H. A. G. E. M. &. K. R. Deveci, "Modified polystyrenes: Corrosion, physicomechanical and thermal properties evaluation. Progress in Organic Coatings," no. https://doi.org/10.1016/j.porgcoat.2011.08.011.
28. Z. H. a. K. M. K. P. Hussain, "The conversion of waste polystyrene into useful hydrocarbons by microwave-metal interaction pyrolysis," Fuel Processing Technology, Vols. Volume 94, , no. https://doi.org/10.1016/j.fuproc.2011.10.009, pp. 145-150, 2012.
29. U. R. E. E. Sunday A. Osemeahon1, "Development of adhesive from polystyrene waste," BIOMED Natural and Applied Science, no. ISSN: 2789-178X, 2022.
30. U. R. E. E. Sunday A. Osemeahon1, "Development of adhesive from polystyrene waste," BIOMED Natural and Applied Science, no. ISSN: 2789-178X, pp. 13-24, 2022.