

Special Issue “Feature Papers in Recycling 2022”

Francesco Paolo La Mantia ^{1,*}  and Beatrice Castellani ^{2,*} 

¹ Department of Engineering, University of Palermo, Viale delle Scienze, 90128 Palermo, Italy

² Department of Engineering, CIRIAF Interuniversity Research Centre on Pollution and Environment “M. Felli”, University of Perugia, Via G. Duranti 67, 06125 Perugia, Italy

* Correspondence: francescopaolo.lamantia@unipa.it (F.P.L.M.); beatrice.castellani@unipg.it (B.C.); Tel.: +39-0912-3863-703 (F.P.L.M.); +39-0755-853-914 (B.C.)

1. Introduction

This Special Issue aimed to collect high-quality papers (original research articles or comprehensive review papers) published during 2022 on the subject of waste recycling. We invited contributions on materials, models and processes involved in the recycling of several types of waste, such as plastic, packaging, e-waste, concrete, magnet waste, slags, and biowaste, in order to develop ways of effectively implementing the principles of circular economy. A wide range of research methodologies was implemented by the authors. This was not only carried out for experimental purposes, but also to assess the role of consumers, industry and policy makers in recycling.

This Special Issue contains 1 review paper and 9 research papers written by 43 authors from countries in Europe (Austria, Italy, Norway, Poland, Portugal, Germany, and Macedonia) and Asia (Malaysia, Thailand, Pakistan, Indonesia, Iraq and UAE), as well as from Canada, New Zealand and Australia. The published papers are discussed in the following section.

2. Research Findings

The findings collected in this Special Issue are organized according to the different methodologies used to define the scope of the research. There is in fact a wide range of methodologies that can be applied to study different types of recycled waste and assess their environmental, economic and social impact. For this reason, the section is divided into: surveys, experimental research, statistical methods, LCA studies and waste management analyses.

2.1. Surveys as a Research Strategy for Waste Recycling

The role of key actors, such as consumers and industries, in recycling pathways can be analyzed through the use of surveys to better understand behaviors, business strategies and the specific issues faced.

In [1], the authors analyzed the effect of users' behavior and intention in the recycling of their mobile phones. Mobile phones are the most used electronic devices globally and they generate millions of tonnes of e-waste. As the authors stated in [1], only 20% of the produced e-waste is recycled worldwide. Since the behavior of consumers is the first step in the recycling chain, it is crucial to determine the factors influencing consumers' decisions.

The methodology used in [1] is based on the administration of a survey to the population of the United Arab Emirates (UAE) that obtained 601 results. The design of the survey was based on the theory of planned behavior (TPB). However, other factors were also taken into account, such as data security and the perceived benefits of recycling.

The results show that environmental and financial benefits and perceived behavioral control are the most significant factors affecting UAE mobile phone users' intention to participate in recycling. The second important factor is attitude and subjective norms, while data security is a crucial aspect for only 7% of users.



Citation: La Mantia, F.P.; Castellani, B. Special Issue “Feature Papers in Recycling 2022”. *Recycling* **2023**, *8*, 60. <https://doi.org/10.3390/recycling8040060>

Received: 17 May 2023

Accepted: 12 July 2023

Published: 13 July 2023



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The study has some theoretical and practical implications, such as the need to increase the knowledge of e-waste recycling education, begin the application of TPB to data security and the perception of benefits, and provide support to the mobile phone industry in reverse supply chain management.

Together with e-waste recycling, the circularity of plastics is a challenge that must be faced if we are to meet our sustainability goals in the near future. The study in [2] used a similar methodology as that used in [1]. However, research has thus far applied it to the role of chief executives of EU manufacturing companies in the uptake of recycled plastic. The author developed a survey questionnaire on the basis of the following factors: attitude, subjective norms, perceived behavioral control, behavioral intention, uptake of recycled plastic and business performance. The author analyzed 291 questionnaires.

The results show that chief executives have positive intentions toward the circularity of plastics, even though many manufacturing companies do not use recycled plastic yet. Therefore, there is a gap between intention and the action for which targeted policies are needed. It is important to underline that the behavioral intentions of chief executives have positive influence on the uptake of recycled plastic in manufacturing companies. In addition, most respondents thought using recycled plastic to be financially rewarding and morally satisfactory.

To improve the scenario, the author suggested some actions, such as governmental motivational campaigns, networking initiatives and platforms among recyclers and companies, and business strategies to reduce operational costs and attract more clients.

Plastic recycling has several technological steps: after sorting and washing, plastic is compounded. The compounding process produces the recycle, after which there is a final step for quality controls before re-introducing the materials in the productive cycle. The study in [3] was based on the analysis of survey questionnaires coming from 20 German recycling compounders to assess the encountered quality problems and related solutions. The study stated that impurities and contaminations in the input material constitute the primary reason for quality problems, independently of the plastic type. The solution is the assessment of input material composition before compounding. However, the use of more constraints in the sorting phase could help. Quality problems easily appear in those companies who manufacture components themselves.

Textile waste from the fashion industry is another significant cause of pollution and has a significant environmental impact. The circularity of textile materials is based on the extension of clothing life through principles of reuse and repair. The purpose of the study in [4] was to assess gender and age factors affecting clothing repair practices through an online survey. It was administrated to 512 Canadian and U.S. consumers. The results show that self-repair is the most used form of repair, with women more disposed to it than men. This attitude increases with age. Men use unpaid forms of repair more than women. However, among young people, unpaid repair is chosen independently of gender. Paid repair has the lowest level of engagement, with no differences observed between genders. The authors suggest that awareness-raising initiatives could motivate consumers to undertake repair. However, also action towards fashion brands should be undertaken in order to push them to replace takeback schemes with repair-based schemes.

2.2. Experimental Research in Waste Recycling

The experimental studies in this SI tested processes of recycling industrial waste. The paper in [5] tested the use of steel slag for mineral carbonation to capture and store CO₂. The experimental methodology consisted of a preliminary chemical and mineralogical characterization of the steel slag, the exposure of the slag to flue gas, and final chemical and mineralogical analyses. The results show that carbonation occurred only on some parts of the surface, with a carbon concentration of 0.5 wt% after almost a month of carbonation, thus presenting slow kinetics. The solubility of the slag increases with carbonation, so the authors concluded suggesting indirect carbonation with the liquid phase to improve carbon capture.

The authors in [6] instead investigated the recycling process of manufacturing NdFeB magnet waste in as-sintered and powder forms. They can be recovered as neodymium (RE) oxides via pyro–hydro metallurgical process. The authors also found the optimum condition for sintered waste, consisting of: (i) oxidative roasting at 600 °C for 1 h; (ii) 2.5 M H₂SO₄ leaching for 24 h; (iii) roasting at 800 °C for 2 h; (iv) water leaching; (v) precipitation with 1 M oxalic acid; and (vi) calcination at 1000 °C for 2 h. They compared two different routes: oxidative roasting—both selective leaching and whole leaching. The first route brought 75–76% recovery, while whole leaching reached only 31–60% due to neodymium loss into leached residue. This research could have an impact on the development of effective recycling technologies to meet the future demand for permanent magnets.

2.3. Statistical Approach

The research in [7] evaluated the effect of biowaste, industrial waste, municipal solid waste and their recycling routs in China on the national carbon emissions using a variety of statistical methodologies: descriptive statistics of the variables, correlation matrix, the ADF unit root test, the ARDL-bounds testing approach, the Granger causality test and the IAM method. The authors used time-series data from 1975 to 2020 on combustible renewables and waste production and recycling.

The results show that unsorted waste is the primary source of mortality and morbidity, with the need of private-public partnerships to manage waste properly. In fact, improvements in waste sorting, collection and final disposal could bring to economic benefits and an increased presence of public-private companies could result in more waste sorting plants and infrastructure. Other crucial points in China are: initiatives of stakeholder involvement and public participation to sorting and recycling and implementation of alternative options to landfill.

2.4. LCA Studies

The LCA approach is a methodology widely used in waste management studies to find the best option in terms of environmental and economic impact. In [8], the authors used LCA results from different sources to compare the production of natural and recycled aggregates for concrete. The authors considered the following parameters to perform the comparison: global warming potential, non-renewable energy consumption, and the cost of 1 tonne of natural and recycled aggregates from cradle to gate. In general, results highly depend on transport distances and costs, with the best environmental results obtained with a low transport distance. Natural coarse crushed aggregates have the highest environmental impact, while recycled coarse aggregates have the lowest one. Recycled aggregates also boast the lowest production costs. The results of this study may help to determine the best solution for use in cement production.

2.5. Waste Management Analyses

Efficient waste management systems are crucial in order to match the high recycling goals set by European Union by 2030. The research in [9] focuses on packaging waste management systems adopted by the UK and several European countries, such as Germany, France, the Netherlands, Portugal, Denmark, Spain, and Italy. Through a comparative description and analysis, the authors depicted non-harmonized national scenarios with specific peculiarities, showing once again how waste management models are strictly dependent on local constraints.

Finally, the authors in [10] completed a review of some issues related to the use of waste materials as binders or aggregates in concrete production. The authors reviewed all the concrete additives recycled from other sectors, such as agriculture, electronics, or the plastics industry, and focused on the final properties of the obtained materials, their optimal compositions, and the related pros and cons. Some of the analyzed solutions seem incapable of producing ecofriendly concrete owing to the presence of harmful chemicals. In

addition, there remain, as in other recycling processes, some gaps to be filled in the future in order to move from lab-scale work to practical applications.

3. Final Remarks and Future Trends

In the opinion of the guest editors, the 10 papers published in this Special Issue contribute to recycling those types of waste with the greatest effect on global pollution, such as e-waste, plastics, construction materials and textiles. In addition to experimental investigations devoted to the development of specific recycling processes, great attention was paid also to the role of the actors, including consumers and industries, in integrating a wide range of research methodologies. Overall, this publication contributes significantly to the implementation of sustainability and the circular economy. This journal is continuing to collect advanced studies in the area of waste reutilization and resource recycling in the upcoming Special Issue, entitled: “Feature Papers in Recycling 2023”.

Acknowledgments: The guest editors would like to thank the MDPI Editorial Office for peer review and publication activities. The guest editors are also grateful to the authors and the reviewers for their precious work in ensuring the high quality of the papers.

Conflicts of Interest: The authors declare no conflict of interest.

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