Environ Monit Assess (2023) 195:233
https://doi.org/10.1007/s10661-022-10842-x

Evaluating strategies for sustainable recovery and recycling of plastic waste in the West Bank of Palestine: The perspectives of plastic companies

Dalia Saadeh · Issam A. Al-Khatib · Fathi M. Anayah

Received: 21 October 2021 / Accepted: 10 December 2022 / Published online: 27 December 2022

Abstract The plastic waste (PW) makes up the second largest portion of the total solid waste generated in Palestine. Hence, it is important to consider proper PW management mainly through recovery and recycling and implement appropriate strategies. This study aims to identify and evaluate the social, legal, technological, environmental, and economic strategies that can positively motivate plastic manufacturing and/or recycling companies to recover and recycle PW. A structured questionnaire was developed to address 30 plastic companies in the West Bank. The results indicate that 80% of the companies supported the social strategies that implement community awareness programs. Almost 92% of the companies agreed with legal strategies which enforce legislations to support PW recovery and recycling practices. As for technological strategies, 76% of the companies endorsed the application of modern technologies for PW management. However, only 68% of the companies accepted the environmental strategies which promote life cycle assessment and environmental awareness programs and adopted the use of recycled plastic materials in manufacturing from the context of the economic and market strategies. Palestinians are invited to implement PW recovery and recycling practices to better utilize available resources, achieve sustainable management of solid waste, and promote environmental health.

Keywords Manufacturing · Plastic waste · Recovery · Recycling · Solid waste · Strategies

D. Saadeh
Universal Institute of Applied and Health Research, Nablus, Palestine

I. A. Al-Khatib
Institute of Environmental and Water Studies, Birzeit University, P.O. Box 14, Birzeit, Palestine

F. M. Anayah (✉)
Faculty of Engineering and Technology, Palestine Technical University – Kadoorie, P.O. Box 7, Tulkarm, Palestine
e-mail: f.anayah@ptuk.edu.ps

Introduction

The solid waste generation is globally growing mainly due to urbanization and economic development, and the generation rate in urban areas is expected to reach 2.2 billion tons/year by 2025 (Schlueter, 2017). Growing waste generation rates require effective waste management to achieve sustainability (Sukholthaman et al., 2017). Municipal solid waste in Palestine includes various waste streams; plastic waste (PW) constitutes the second largest proportion (Al-Khatib et al., 2010, 2020; Sweepnet, 2014; Thoni & Matar, 2019). Plastic products are frequently applied in our daily life, e.g., covering, wiring, containers manufacturing, packaging, and others (Brems et al., 2012; Mwanza & Mbohwa, 2017). Plastic materials range from rigid to flexible

substances, fibers, foams, and adhesives (Napper & Thompson, 2020). Given plastics low density, light weight, durability, corrosion resistance, high strength, low cost, and diverse applications, the overall plastics usage and hence PW generation rate have considerably increased (Brems et al., 2012; Hopewell et al., 2009; Lopez et al., 2017; Mwanza & Mbohwa, 2017).

Overall, the global production of plastics reached 359 million tons in 2018 (Napper & Thompson, 2020) of which Middle East/Africa and Europe produced 7 and 17%, respectively (PlasticsEurope, 2019), One year later, 370 million tons of plastics were produced in the world (Kumar et al., 2021). By the end of 2020, the total PW to be generated was estimated at 585 million tons by 7.7 billion people in the world (Benson et al., 2021). The annual production of plastic is predicted to be doubled in the next 20 years (Napper & Thompson, 2020). This inevitably indicates the huge amounts of PW generated by the developed countries compared to the tiny contribution of the developing countries including Palestine.

Having anticipated this fact, scientists have long researched and practiced various methodologies to manage PW sustainably (Mwanza & Mbohwa, 2017). Plastics degradation has a long timeframe, and usually smaller pieces of plastic debris (e.g., microplastics) have a higher impact on water pollution (Napper & Thompson, 2020), contributing to both waste management issues and environmental damage (Hopewell et al., 2009). The plastic contamination is classified by size into three categories: macroplastic (>20 mm diameter), mesoplastic (5–20 mm), and microplastic (<5 mm) (see Napper & Thompson, 2020). Packaging represents the largest consumer (37%) in the plastic market, followed by the building and construction industry (21%) and the automotive industry (9%), and the remaining share is distributed for household and domestic applications (Brems et al., 2012).

The methods to properly manage PW include recovery, recycling, incineration, and sanitary landfilling, while burning, open dumping, and littering are the possible destination for unmanaged PW (Shen et al., 2020). Generally, the recovery process means that plastic waste is neither landfilled nor littered, while recycling process signifies to manufacture a new product using the recovered plastic waste (Hopewell et al., 2009). Incineration and landfilling are the most common methods used for PW management in several countries such as the USA, Brazil, Germany, and India (Hossain et al., 2021). Out of the PW collected in the world, 42.6% is recovered for energy, 32.5% is recycled, and 24.9% is landfilled (Baran, 2022; PlasticsEurope, 2019). Yet, recent studies have even shown larger percentages of PW being disposed of into the environment or landfilled in Palestine (Anayah et al., 2021; Thoni & Matar, 2019) and the globe (Chamas et al., 2020; Kumar et al., 2021).

Landfilling is the least preferred option and should be applied only for the residuals of the aforementioned practices since most types of plastics are not biodegradable, and therefore, the majority of polymers manufactured today will span several decades and centuries (Chamas et al., 2020; Hopewell et al., 2009; Ncube et al., 2021; Shen et al., 2020). Also, degradable plastics may persist for a considerable time depending on the chemistry of the polymer (Napper & Thompson, 2020) and the local environmental factors (Alhazmi et al., 2021; Brems et al., 2012). Despite the fact that waste-to-energy practices are largely applied in developed countries (PlasticsEurope, 2019), they constitute the least preferred option for developing countries due to the existing poor infrastructure (Ncube et al., 2021), technological limitations, and operating costs (Lopez et al., 2017), as well as health and environmental hazards (Hossain et al., 2021). Therefore, the circular economy and resource efficiency principles need to be considered for a successful PW management (Baran, 2022; Kumar et al., 2021).

Recycling is considered the dominant practice for PW management and is backed-up by waste-to-energy (Al-Salem et al., 2009) and landfilling (Hossain et al., 2021) applications. Effective and efficient recycling entails waste segregation at the source so that each waste category is collected separately (Al-Salem et al., 2009; Ncube et al., 2021). PW recycling can be considered the second environmentally sound strategy after the source reduction strategy. The contribution to global warming at the different stages of plastic life cycle is evident (Chitaka et al., 2020; Mwanza & Mbohwa, 2017; Shen et al., 2020). The application of PW recycling in manufacturing processes, as an example, contributes to greenhouse gas emissions and carbon footprint reduction (Gu et al., 2017; Lopez et al., 2017; Shen et al., 2020; Zheng & Suh, 2019).

Through PW recovery and recycling applications, natural resources and consumed energy may be conserved, transportation and disposal costs could be reduced, and as a result, both sustainable manufacturing and resource management would be attained (Brems et al., 2012; Ncube et al., 2021; Shen et al., 2020). Besides circular economy rules support recycling practices since they develop secondary materials to feedback manufacturing, by diverting the materials bearing economic value from the waste stream, and therefore, reducing the total quantity of waste to be managed (Kumar et al., 2021; Napper & Thompson, 2020; Ncube et al., 2021; PlasticsEurope, 2019). Also, recycling provides the opportunity to innovate by manufacturing new products from recovered plastics, decreasing at the same time the impacts resulted from the end of use post-consumer packaging plastic wastes (see Gu et al., 2017; Ncube et al., 2021).

Although many studies have been conducted on PW recycling, the majority of them apply the methodology of life cycle assessment to evaluate the environmental, economic, and social impacts of the processing and recycling chain (Al-Salem et al., 2009; Chitaka et al., 2020; Gu et al., 2017; Kumar et al., 2021; Ncube et al., 2021). Other studies have focused on recycling and recovery routes of PW indicating the necessity to consider the application of both recycling and waste-to-energy recovery methods in plastic manufacturing facilities (Al-Salem et al., 2009; Gu et al., 2017; Hopewell et al., 2009; Ncube et al., 2021; PlasticsEurope, 2019; Shen et al., 2020). Finally, yet importantly, few studies have analyzed the strategies to sustainable PW recovery and recycling (Lopez et al., 2017; Mwanza & Mbohwa, 2017; Mwanza et al., 2018; Zheng & Suh, 2019).

In developing countries, the issue of PW recycling is remaining a challenge. In Palestine, the PW generation rate is between 14 and 17% of the total waste generation (1.387 million tons) of which less than 1% is recycled (Al-Khatib et al., 2020; Sweepnet, 2014; Thoni & Matar, 2019). PW is classified into seven categories: polyethylene, high-density polyethlyene, polyvinyl chloride, low-density polyethylene, polypropylene, polystyrene, and others (Thoni & Matar, 2019). The polyethylene and polypropylene are the most common PW recycled in Palestine (Al-Khatib et al., 2020). In the West Bank, a total of 869 tons of PW was recycled in 2010 (Sweepnet, 2014). The PW recovery and recycling market in Palestine is small, informal, risky, and fluctuating, while the legislations do not motivate any involvement of the private sector (Saadeh et al., 2019; Thoni & Matar, 2019).

Therefore, challenges of managing municipal solid waste particularly PW in Palestine are still rising in diverse institutional, organizational, technical, political, financial, and environmental contexts (Al-Khatib et al., 2010, 2020; Sweepnet, 2014; Thoni & Matar, 2019; Anayah et al., 2021). The Palestinian National Strategy of Solid Waste Management (NSSWM) was first approved in 2010 (Sweepnet, 2014) and updated in 2017 (Thoni & Matar, 2019). Given the limited financial and technical resources in Palestine (Al-Khatib et al., 2010, 2020), the NSSWM promotes separation and 3Rs (reduce, reuse, and recycle) principles of waste management utilizing all possible new technologies (Thoni & Matar, 2019). The bottom point is that there is an urgent need to bridge the gap among waste management policies or strategies and their practical application on the ground (Al-Khatib et al., 2010; Anayah et al., 2021; Thoni & Matar, 2019). Therefore, various policies, laws, bylaws, resolutions, initiatives, programs, and plans were established in Palestine in order to achieve the objectives of the NSSWM (Sweepnet, 2014; Thoni & Matar, 2019).

In the last few decades, the plastic industry had grown fast in Palestine. According to the United Nations International Trade Statistics, Palestinians imported plastics worth of $200 million in 2014, and this amount approached $255 million value in 2018 (Dweik, 2021). Recently, Palestinians exported $152 million worth of plastic materials of which 56% were sent to Israel, mostly as packaging materials (Dweik, 2021). The plastic manufacturing and/or recycling companies in Palestine need to be aware of such trends in the plastic industry as the future is promising, particularly with effective public participation.

The objective of this paper is to outline the main strategies that could encourage plastics manufacturing and/or recycling companies in the West Bank to recycle PW and use secondary raw materials of plastic in their production line. In order to understand the personal views of stakeholders, an extended survey was conducted through in-person interviews guided by a structured questionnaire as a means to collect required data.

Methodology

In order to achieve the objectives and obtain quantitative data for this study, information on the number of plastic manufacturing and/or recycling companies in the West Bank were gathered through the Palestinian Plastic Industries Union (PPIU) archive at the head office in Hebron governorate. The PPIU is a member of the Palestinian Federation of Industries which was established in 2006. According to the PPIU archive, 86 plastic manufacturing and/or recycling companies in the West Bank are current members of the PPIU. However, the biggest and most influential companies (in terms of production rate and customer number) were contacted to maintain a representative sample.

A simple and structured questionnaire was prepared and pre-tested. The questionnaire aimed to collect information about the agreement of the plastic companies with the proposed strategies under the social, legal, technological, environmental, and economic and market aspects. In order to apply content validity of the questionnaire, an exhaustive literature review was conducted to extract the related items, the questionnaire was revised by three experts in the same field of the research, and five plastic manufacturing and/or recycling companies that were excluded from the survey were interviewed as a pre-examination of the questionnaire. Table 1 depicts the 30 plastic manufacturing and/or recycling companies located in Hebron, Ramallah and Al-Bireh, Bethlehem, Nablus, Jenin, Qalqilya, and Salfit governorates that were contacted in the frame of this research. As shown in Fig. 1, the West Bank consists of 11 governorates in which most of the plastic companies (22 out of 30) are specifically located in Hebron and Ramallah and Al-Bireh governorates. This is not a surprise as the Hebron and Ramallah and Al-Bireh governorates are the capital cities of industrial and commercial activities, respectively, in the West Bank.

All pinpointed aspects were transmuted into potential strategies potentially affecting PW recovery and recycling rates in the West Bank of Palestine. The strategies are formatted in a structured questionnaire which was initially emailed to the target companies listed in Table 1 and filled out by a representative from each company. Table 2 shows the main 20 strategies proposed under the social, legal, technological, environmental, and economic and market aspects. The questionnaire consists of an introductory paragraph showing the goal and importance of the proposed study, basic information about the plastic manufacturing and/or recycling company, and the 20 statements to address the five aspects of interest. The questionnaires were completed through personal interviews with the target companies, resulting in a response rate of 100%.

The statements of the questionnaire were designed following the 5-point Likert-type scale. In this five-level ordinal scale, the respondents were asked to specify their levels of agreement or disagreement on a symmetric agree-disagree scale for different statements. In the questionnaire, the respondent was asked to react to each statement in terms of several degrees (agree strongly, agree slightly, neutral, disagree slightly, and disagree strongly). In this case, the respondent has the flexibility to express his/her views freely, unlike to 2-point Likert scale in which respondents feel they have to sharply and literally answer with agree or disagree. This 5-point scale is one of the most common choices for researchers who seek to strictly measure the opinion (data) of the target audience on a particular topic (DiStefano et al., 2020; Jeong & Lee, 2016; Timbrook et al., 2021). This particular scale of the questionnaire is typically easy to design, understand, use, and interpret (DiStefano et al., 2020), making it most appropriate to the present study.

Due to the limited number of respondents in the present study, the 5-point response scale can be easily and reliably collapsed into a bipolar or dichotomized scale (Jeong & Lee, 2016). The three responses of agree strongly, agree slightly, and neutral from the original 5-point scale are collapsed to an "agree" category, while the disagree slightly and disagree strongly responses are collapsed to a "disagree category. Such collapsing algorithms are advised in the analysis stage of the data collection process to obtain robust results without sacrificing performance (DiStefano et al., 2020; Jeong & Lee, 2016). The simple bipolar design of the responses may help yield a straightforward assessment of the respondent directions (agree versus disagree) to the statements and draw rigorous conclusions about PW recovery and recycling strategies in Palestine. Descriptive statistics (e.g., average values) were used for data analysis and computation by the use of the Microsoft Excel program.

Following that, face-to-face interviews were also conducted to elaborate on the research purpose

Table 1 Most important plastic manufacturing and/or recycling companies in the West Bank and their respected location (source: PPIU, Hebron)

No	Plastic company	City	Governorate
1	Al-Ameer Plastic Manufacturing and Trading Company	Sair	Hebron
2	Al Alamyeh for Plastic Manufacturing	Hebron	
3	Al-Rahma for Plastic Industries	Hebron	
4	Al-Saafeen Brothers Company for Plastic Trade	Hebron	
5	Al-Taqaddum Plastic Industries Company	Hebron	
6	Al-Wafa Plastic Company for Plastic Industries	Hebron	
7	Allian for Plastic Industry	Hebron	
8	Bright Stars Company for Plastic Trading and Manufacture	Hebron	
9	Epco Plastic Company	Hebron	
10	Injaz for Plastic Manufacturing Company	Hebron	
11	J.L.T. for Plastic Industries	Hebron	
12	M Company for Plastic Manufacturing Company	Hebron	
13	National Plastic Industry	Beit Ummar	
14	Abdeen Industrial Trading Company	Baytunia	Ramallah and Al-Bireh
15	Elian Industrial and Trading Company	Baytunia	
16	Elite Plastic Industries and Investment Company	Ramallah	
17	Esberg Manufacturing and Trading Company	Ramallah	
18	Jamjoom Company for Manufacturing and Trading	Ramallah	
19	National Manufacturing Company	Ramallah	
20	Rabah Plastics Company	Ramallah	
21	Tech Plast Company for Industrial Engineering	Baytunia	
22	Tel Plastic for Engineering Manufacturing Company	Ramallah	
23	Bethlehem Plastic Company	Bethlehem	Bethlehem
24	Crystal for Plastic Manufacturing	Bethlehem	
25	Nablus Plastic and Nylon Company	Beit Eba	Nablus
26	Plastic Technology Company	Nablus	
27	Crown Company for Plastic Industries	Jenin	Jenin
28	Jabareen Company for Plastic Products, Printing and Packaging	Jenin	
29	Yasser Mansour Company for Industry and Trade	Qalqilya	Qalqilya
30	Dalia Plastic Precision Works	Biddya	Salfit

and to encourage and support the questionnaire responses by the target audience. The interviews are intended to overcome the primary problem of the agree-disagree scale which is prone to acquiescent reports indicating a positive bias of the respondents to the questionnaire statements (Timbrook et al., 2021). The outcomes from 30 plastic manufacturing and/or recycling companies of the target audience were thoroughly compiled to categorize, sort, and analyze all retrieved data. The response distribution was basically analyzed by calculating the percentage of respondents who agree with each strategy.

Results and discussion

It is important to encourage the private sector and manufacturing industries to recover and recycle PW and target at achieving sustainable production patterns (Saadeh et al., 2019). Additionally, it is rather significant to identify the specific reasons that hinder the application of PW recovery and recycling in large scale. It is also to investigate the result with the application of previously identified good practices or the application of innovative strategies in PW recovery and recycling. Existing good practices in other

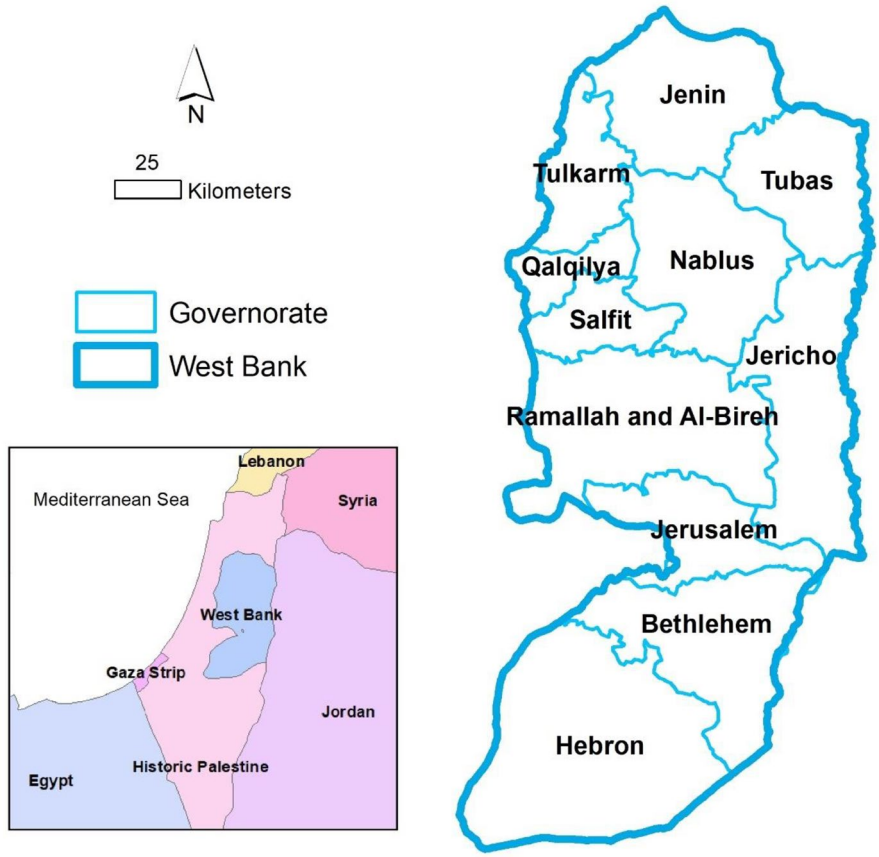

Fig. 1 The geographic location of the West Bank governorates in Palestine

countries may improve the implementation of strategies in the Palestinian sector of PW recovery and recycling. Such learning process requires the careful consideration of local social, legal, technological, environmental, and financial aspects (Al-Khatib et al., 2020; Mwanza & Mbohwa, 2017). In this study, all these mentioned aspects were evaluated from the perspectives of the plastic manufacturing and/or recycling companies to enhance plastic sustainable manufacturing and waste management in the West Bank. The significance of each aspect is determined and discussed based on the local conditions and compared to the international experience.

Social aspects

Social considerations, when a recovery and recycling program is applied, are rather important to the integrity of a sustainable waste management system. Raising local residents' awareness level on environmental issues motivates and encourages their participation in recovery and recycling schemes. Given that residents are provided with a clear plan and methodology, public involvement in PW management activities may increase (Benson et al., 2021). According to Hopewell et al. (2009), Australians participated in recycling schemes more than the British people as Australians performed curbside collection for a longer period of time.

Following that and aiming to alter the production and consumption patterns of residents, decision makers may motivate manufacturers and local authorities to produce recycled products and improve waste/recyclables collection correspondingly. Several marketing studies on consumer preferences (European Union, 2018) pinpoint a significant proportion of people who value environmental issues in their purchasing habits. To this direction, the manufacturing sector, for its own economic viability, needs to take into consideration pro-environmental attitudes and awareness of consumers and alter production lines accordingly.

Table 2 Strategies under the social, legal, technological, environmental, and economic and market aspects

Aspect	Strategies
Social	1. Raising awareness of students by having PW recovery and recycling curriculum for school education 2. Developing and implementing community awareness programs, aiming at supporting consumer attitude towards PW recovery and recycling 3. Using incentives to motivate PW recovery and recycling at household levels 4. Introducing segregation of PW at household level for further recovery and recycling practices 5. Implementing joint projects with civil society institutes to familiarize the informal sector with the importance of PW recovery and recycling
Legal	6. Establishing and enforcing policies, laws, rules, and regulations on PW recovery and recycling 7. Enforcing producer responsibility regulations to encourage PW collection 8. Legalizing selective collection done by PW pickers from households, retailers, dumpsites, etc 9. Creating standards and certification schemes for PW recyclers
Technological	10. Introducing new PW recovery and recycling technologies 11. Advancing PW washing and sorting technologies 12. Developing PW size reduction technologies 13. Ensuring that recovered and recycled PW is to be reused again in manufacturing processes
Environmental	14. Conducting life cycle analysis to evaluate PW recovery and recycling practices and their impacts 15. Encouraging environmental awareness programs
Economic and market	16. Limiting the cost of PW recovery and recycling (low energy requirements, smart transportation systems, etc.) 17. Ensuring that the price of recovered and recycled PW is competitive in comparison with virgin plastics 18. Promoting the consumption of recovered and recycled PW in manufacturing processes 19. Enhancing development of domestic market to rely on recovered and recycled PW 20. Encouraging recyclers to have good relations and communications with municipalities, retailers, and sorters

Considering the social strategies, 52% of the plastic companies agreed with the strategy referring to raising awareness of students by having PW recovery and recycling curriculum for school education. However, 80% of the companies agreed with the strategy involving the development and implementation of community awareness programs, aiming at supporting consumer attitude towards PW recovery and recycling. Awareness programs might target consumers and change their behavior regarding plastic use and disposal from linear to circular approach (Baran, 2022; Mehta et al., 2021). The plastic companies request immediate action from community members, rather than long-term cooperation of next generation. At the household level, for instance, children are typically more likely to imitate the attitudes, perceptions, and practices of their parents. Still, raising awareness of school students on PW recovery and recycling methods is indeed an integral part to curb the problem in the short run and alleviate its detrimental impacts in the long-run (Ncube et al., 2021).

Almost 48% of the plastic companies agreed with the strategy about using incentives to motivate PW recovery and recycling at household levels, while 56% of the plastic companies agreed with the strategy on introducing segregation of PW at household level for further recovery and recycling practices. This low level of agreement came from the truth that the financial and non-financial motivations are not the key to positively change the attitudes of residents at the household level; it is the prevailing culture of the local community. Local residents believe that they pay for solid waste collection, and therefore, service provider is responsible for any segregation, treatment, and disposal processes.

Finally, 72% of the plastic companies stated that they agree with the implementation of joint projects with civil society institutes to familiarize the informal sector with the importance of PW recovery and recycling. The involvement of civil society institutes or non-governmental organizations is crucial in the solid waste management system (Thoni & Matar, 2019) to secure financial and technical assistance resources (Saadeh et al., 2019). Typically, these institutions are financially supported by the private sector at local scale and/or the donor agencies at regional and global scales. Figure 2 shows the percentages of the plastic companies support the proposed social strategies that

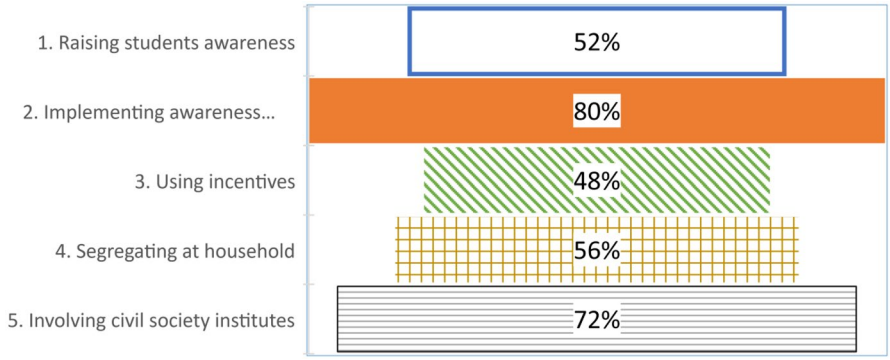

Fig. 2 Percentages of agreement of the plastic companies with the proposed social strategies

can influence individuals and communities participate in the recovery and recycling programs of PW.

Developing and implementing community awareness programs on PW recovery and recycling practices had the highest percentage of agreement (80%) out of all social strategies. This outcome is in agreement with other studies in developed countries. According to a survey conducted in 2006, only 57% of the British population participated in recycling schemes, while 80% of the Australians performed curbside collection once awareness programs had been implemented (Hopewell et al., 2009).

There is no doubt that community education and awareness strategy that focuses on citizens will increase the participation rates on PW recovery and recycling. The environmental attitude towards PW recovery and recycling will be directly enhanced affecting efficient consumption of resources and then create an impact in sustainable production/manufacturing as well. Under these circumstances, the manufacturers will be encouraged to organize PW collection and produce recyclable plastic products. The strategy should be supported by being harmonized to initiatives already implemented on ground and create cooperation patterns that will affect the overall waste management sector.

Legislative aspects

One of the most important activities in solid waste management is the "3Rs" activities which are carried out with involved stakeholders in the society including waste generators, households, commercial and business establishments, schools, hospitals, and government agencies. In order to obtain the support from the society, raising public awareness is one of the key issues for successful implementation of the 3Rs activities. The 4Rs (reduce, reuse, recycle, and recover) principle, however, was also introduced for a sustainable system of waste management, given that landfilling is the least preferred option (Hopewell et al., 2009). The implementation of the 4Rs principle in solid waste management helps communities achieve the sustainable development goals launched by the United Nations (Kumar et al., 2021). The introduction of strategies, policies, laws, principles, and directives in solid waste management cannot be successful with no enforcement from competent authorities (Al-Khatib et al., 2010; Anayah et al., 2021; Hossain et al., 2021; Ncube et al., 2021; Thoni & Matar, 2019).

Legislations are considered as one of the strategies encouraging recovery and recycling of PW. In multiple developed countries, legislations obligated many industries to set up systems for safe disposal and product recovery of PW. A European directive imposed a 65% reduction of recyclable waste to be landfilled between 1995 and 2010 (Brems et al., 2012). Therefore, the European industry has to promote PW recovery and recycling options for an effective waste management. It was found that higher rates of PW recovery and recycling are noticed in countries with landfill restrictions of recoverable and recyclable waste (PlasticsEurope, 2019) and those with the option of waste exportation to global markets such as China and India (Brems et al., 2012). In 2018, three European countries, namely, Switzerland, Austria, and Netherlands, had approached a zero landfilling target to achieve the circular economy of plastics (Baran, 2022; PlasticsEurope, 2019).

Furthermore, England and Germany enacted the extended producer responsibility to implement

recovery and recycling of packaging through the "Green Dot" scheme (Hopewell et al., 2009). As a result, the market value of recycled materials and the viability of recycling have increased over the last few years. A good example is Japan in which the extended producer responsibility raised the recycling rates to 70% between 1995 and 2010 (Mwanza et al., 2018).

Considering the legal strategies, 92% of the plastic companies agreed with the establishment and enforcement of policies, laws, rules, and regulations on PW recovery and recycling, while 64% of them agreed with the enforcement of producer responsibility regulations to encourage collection of PW. The high agreement levels of legislation updates on PW recovery and recycling issues indicate the dire need for a comprehensive legal framework. Such a framework must involve rules, guidelines, and specific standards, which could potentially set the basis and encourage manufacturers to invest and install proper systems for PW recovery and recycling. Inevitably, the later will increase recovery and recycling rates and reduce landfilling. In the same time, plastic companies should hold some responsibility to encourage PW collection. Policy makers should enact proper policies and laws to motivate and enforce residential, commercial, and industrial producers to separate and collect PW from other solid waste.

Thus, it is not surprising that 48% of the plastic companies supported the legalization of selective collection done by waste pickers from households, retailers, institutions, and dumpsites. It is the responsibility of all community members to support and participate in the separation and collection of PW. Almost 88% of the plastic companies agreed with the creation of standards and certification schemes for PW recyclers. This reflects the need for a regulatory system that organizes PW recovery and recycling activities. The policy maker should make sure that key stakeholders understand their roles, authorities, and responsibilities in the management system of the plastic industry (Kumar et al., 2021; Mehta et al., 2021; Ncube et al., 2021). Figure 3 shows these outcomes through the acceptance level of plastic companies to the proposed legal strategies.

Technological aspects

Technological advancements play a significant role in decreasing the cost of recycled plastic constituting the secondary plastic raw material similar to the original one in terms of cost and effectiveness as well (Baran, 2022; Hossain et al., 2021; Mwanza et al., 2018; Ncube et al., 2021; Shen et al., 2020). Technology advancements made it easy for certain European countries such as Spain, Austria, Italy, Norway, and Germany to recycle rigid and flexible packaging materials (Hopewell et al., 2009). Certain washing and sorting technologies encouraged these countries to extend PW recycling to non-bottle packaging materials (Baran, 2022; Hopewell

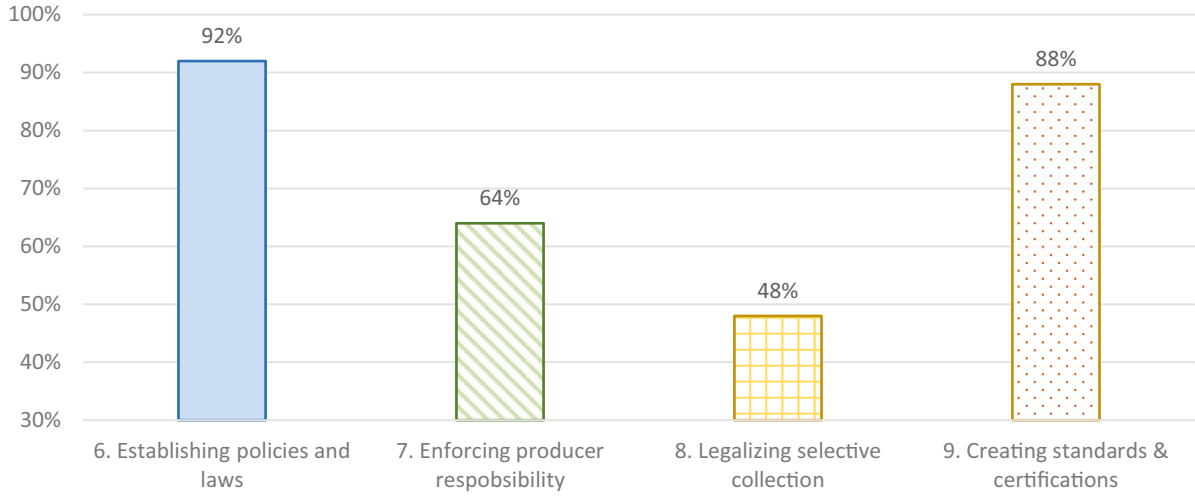

Fig. 3 Percentages of agreement with legal strategies as ranked by the plastic companies

et al., 2009). Typically, developing economies learn from developed economies that own the technologies and create innovative solutions to global environmental challenges. Yet, many waste management options, which had been successfully adopted in several developed economies, were not necessarily feasible in developing economies (Alhazmi et al., 2021).

Considering the technological strategies, the development of new recovery and recycling technologies for PW had the highest agreement score (76%). In general, new technologies of PW recovery and recycling boost up performance and cut up manufacturing costs (Baran, 2022). Further on, 52% of the plastic companies agreed that the advancement in PW washing and sorting technologies should be considered, while 60% of them supported the development of size reduction technologies of PW. Finally, only 44% of the plastic companies agreed with the strategy that forces the reuse of recycled plastic in manufacturing processes. Reusing recycled plastic while keeping product quality is still a challenge to plastic companies. A developing country such as Palestine has neither manufacturing activities nor technical capacities to perform these technologies and implement the 3Rs activities. Table 3 depicts the outcomes on the technological strategies ranking from the perspective of the plastic companies.

Due to constant technological advancements and new recovery and recycling technologies, the PW market and industry will save money, energy, and time and will be further encouraged to collect different types and amounts of PW to be recovered and recycled locally. The collected PW types may be extended in time to include other products additional to packaging ones, e.g., trays, tubs, pots, films, and wrappers (Brems et al., 2012; Hopewell et al., 2009; Ncube et al., 2021).

Table 3 Percentages of agreement with technological strategies as revealed by the plastic companies

Strategy	Agreement percentage (%)
10. Introducing new technologies	76
11. Advancing washing and sorting	52
12. Developing size reduction	60
13. Reusing in manufacturing	44

Environmental aspects

One of the main benefits of PW recycling is to reduce the requirement for plastic raw material manufacturing. A comprehensive review of existing life cycle assessment studies to assess the environmental impacts of the different management options of PW had been recently conducted by Alhazmi et al. (2021). The life cycle assessment clearly shows the benefits of PW recycling that results in reduced amounts of fuels to consume and greenhouse gases to generate (Kumar et al., 2021; Mwanza & Mbohwa, 2017). Another aspect is the evaluation of the net environmental impacts of PW recycling (Gu et al., 2017; Napper & Thompson, 2020; Perugini et al., 2005), which are high compared to the application of landfilling and incineration (Alhazmi et al., 2021). For example, recycling produces more energy than the other alternatives as well as more greenhouse gases caused by additional transportation needed (Alhazmi et al., 2021).

A study in Germany found that the use of recycled plastic (polyethylene terephthalate) instead of original plastic reduced the full life cycle emissions by 27% (Hopewell et al., 2009). New environmental challenges have arisen due to the emerging problems, and therefore, the present study did not address each and every issue in this regard. The onset of the coronavirus pandemic has heavily posed global threats to the public health and the environment and generated about 1.6 million tons of PW each day (Benson, et al., 2021). Due to the coronavirus pandemic, reduced rates of refuse collection and curbside disposal increase the amounts of raw materials ready for recycling in developed countries, yet lead to waste mismanagement in developing countries (Ncube et al., 2021).

Excessive use and reuse of plastic products and personal protective equipment have been obviously noticed as a result of the coronavirus pandemic and largely led to global PW problems (Benson, et al., 2021). Many countries in the world suspended some recycling programs of domestic and medical waste to limit the spread of the coronavirus pandemic (Benson, et al., 2021). More stringent strategies are required to assess the environmental impacts of multiple PW

management options during the coronavirus pandemic and after the lockdown period (Benson et al., 2021; Ncube et al., 2021).

Considering the environmental strategies, encouraging life cycle analysis to evaluate PW recovery and recycling practices and their impacts and encouraging environmental awareness programs had the same score on the Likert scale with a 68% agreement percentage. The findings revealed the positive perceptions of most plastic companies towards the environment. Life cycle analysis is very important to determine the benefits of PW recovery and recycling programs. For example, if plastic manufacturers use recovered and recycled PW, the pollutants and emissions generated from plastic manufacturing processes will be reduced (Mehta et al., 2021; Mwanza & Mbohwa, 2017).

Furthermore, environmental awareness and education are also crucial strategies that will surely improve the environmental performance of the plastic industry (Mwanza & Mbohwa, 2017; Napper & Thompson, 2020; Alhazmi et al., 2021; Benson et al., 2021). Environmental awareness and education programs include the people (members of the public) who are involved in the use and disposal of plastics, as well as the different stakeholders who are in charge of the plastic industry. Informing plastic consumers about the environmental impact of plastic manufacturing processes as well as options to manage the PW could benefit the plastic industry (Kumar et al., 2021; Mehta et al., 2021).

Economic and market aspects

The success of PW recycling depends on the price of recycled PW in comparison with original plastic materials and the cost of recycling processes compared with the expenditures of other alternative practices (Hopewell et al., 2009). Economic benefit inevitably motivates people's willingness to recycle solid waste and PW in particular. For example, Japanese generated supplementary incomes by exporting recyclable plastics as a secondary input material, and so did Malaysians (Mwanza et al., 2018).

In general, the quality of recycled plastics is lower than the original plastic (Hopewell et al., 2009; Alhazmi et al., 2021). Hence, the maximum price of the recycled plastics is usually determined by that of the original one. Lately recycled plastics have become profitable since the price of original plastics is affected by the oil price (Shen et al., 2020) which has increased significantly (Brems et al., 2012; Hopewell et al., 2009). Moreover, market-share is also important in PW recycling. It is important for recyclers to have good relations and deal with the municipalities, retailers, and sorters, and this will enhance and promote recyclability.

Globally, the plastic production is the largest in China, followed by Europe and North America (Shen et al., 2020). In 2011, a total of 15 million tons of PW were recycled in the domestic market of China (Mwanza et al., 2018), and this amount might approach 108 million tons by 2020 (Benson et al., 2021). In 2018, 9.4 million tons of PW were collected for recycling in Europe, and the plastic industry made 28.8 billion euros to public finance and welfare with a turnover of more than 360 billion euros (PlasticsEurope, 2019). In the USA, almost 3.17 million tons of PW were recycled in 2014 (Shen et al., 2020), while this total estimated PW may reach up to 25 million tons by 2020 (Benson et al., 2021). Out of the total estimated PW generated by the end of the year 2020 (585 million tons), almost 82% is generated by the top 35 countries listed by Benson et al. (2021).

Considering the economic and market strategies, promoting the consumption of recovered and recycled PW in manufacturing processes had the highest score (68% agreement level). However, the strategy of limiting the cost of PW recovery and recycling compared to the price of virgin plastics was also high enough (60% agreement) to the plastic companies. Both the rising prices of raw materials and the commodity price volatility have led plastic manufacturers to search for feasible alternatives. Still, the plastic companies hesitate to give recovered and recycled PW a try, and they want real examples to prove that product performance is not compromised.

While encouraging recyclers to have good relations and communications with municipalities, retailers, and sorters was supported by 52% of the plastic companies, it is believed that effective communication must be of the two-way type under which a win–win situation takes place. The initiatives of such communication should come from the public sector, while those come from the private sector are typically accused to be merely driven by profit. This is the role of both the governmental agencies and the civil society institutions to

establish clear and consistent communication channels with private companies for the public interest (Saadeh et al., 2019).

However, promoting development of domestic market to rely on recovered and recycled PW was the strategy with the agreement of only 44% of the plastic companies. In contrast to papers, metals, and glasses, the PW recovery and recycling remain a global challenge that has significant impacts on economy, health, and the environment (Anayah et al., 2021; Baran, 2022; Kumar et al., 2021). The PW recovery and recycling is only applied on specific types of plastic, and instead most PW is littered, incinerated, or landfilled. The low fees municipalities pay to landfill solid waste could not only reduce the motive to recover and recycle PW, but also undermine the economic significance and the value of these processes. Plastic litter, however, does not only raise social costs and economic losses, it also endangers human health and the environment (Benson et al., 2021; Kumar et al., 2021).

Overall, it is rather certain that cost minimization leads to immediate increase of profits, but investing in the environmental aspects of each company operations may lead into higher profits in the long run. This aspect needs plastic companies to be intensively communicated to stakeholders encouraging them to increase the use of recovered and recycled PW and keep its demand to the highest levels possible in the local market. In this way, a win–win situation is created among plastic companies. Figure 4 summarizes the results on the economic and market strategies with a focus on plastic companies.

All aspects

As shown in Fig. 5, the social and legal aspects are the most concerning strategies from the perspective of the plastic companies. Unexpectedly, economic and market aspects are the least important strategies to the plastic companies, showing more interest to environmental and technological aspects to recover and recycle PW. Although there were only two strategies to propose to the plastic companies, it looks like these companies have paid more attention to the environmental challenges the Palestinians need to tackle regarding the solid waste management, particularly the PW.

To sum up, the results of this study indicate that the strategies that need to be undertaken in the West Bank of Palestine, from the perspective of the plastic manufacturing and/or recycling companies, involve the development and implementation of awareness programs for individuals and communities; the establishment and enforcement of updated policies, laws, rules, and legislations on PW recovery and recycling; the introduction of new recovery and recycling technologies; and the support of local plastic companies to increase the consumption of recovered and recycled PW in their production lines.

Under the same perspective, the Palestinian national strategy of solid waste management needs to be updated to cover the aforementioned proposed strategies as well as to monitor their outcomes frequently. The later will not only support the implementation of PW recovery and recycling schemes and programs, but also it will sustain the management of solid waste systems in general. Given that in the presented research the focus is on the PW streams from

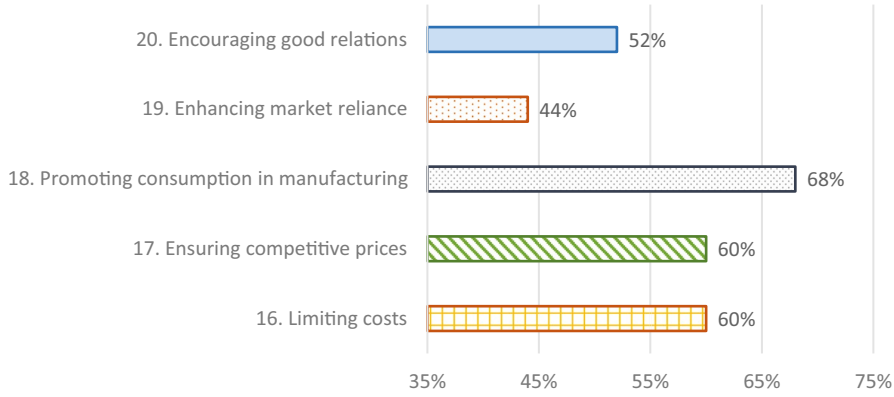

Fig. 4 Percentages of agreement with economic and market strategies proposed from the perspective of the plastic companies

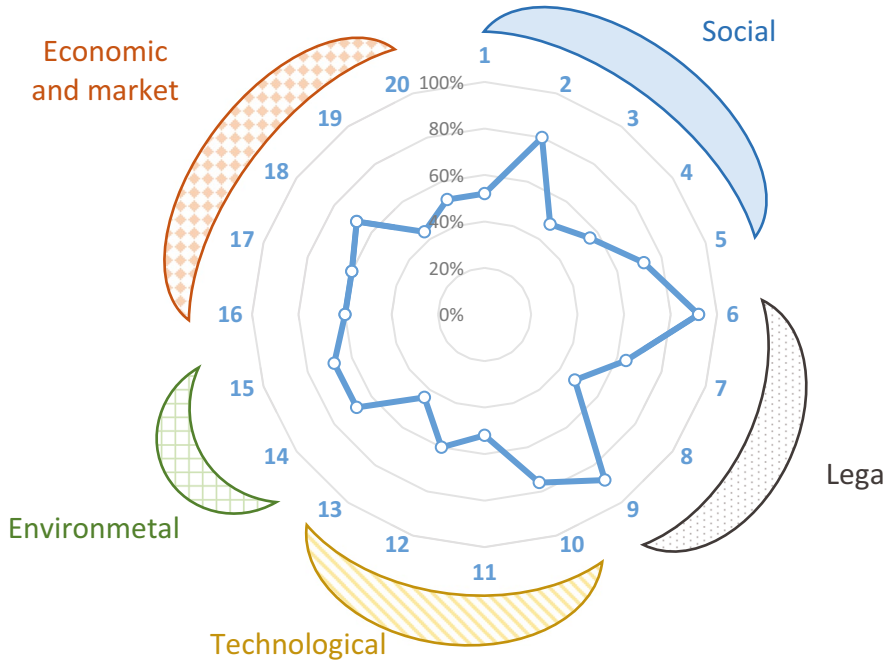

Fig. 5 Percentages of agreement with the 20 proposed strategies from the perspective of the plastic companies

the plastic companies' perspectives, the role of citizens at the household level does not necessarily seem to be less important as shown in other studies (Basaran, 2012; Mwanza & Mbohwa, 2017; Mehta et al., 2021; Ncube et al., 2021). Taking into consideration the literature, both communities and households have an important role to play in solid waste management, and their scopes should be blended with the perspectives of manufacturing and/or recycling companies to achieve sustainability locally and globally.

Furthermore, all aspects analyzed in the frame of this paper are important to consider a conglomeration of issues that need to be respected and constitute the baseline for any scheme developed at the individual and community levels. Neither the social nor the economic aspects should stand out in any case to develop a win–win situation; instead the full cooperation of all stakeholders considering the different aspects is still a key solution to environmental challenges. It is mainly the responsibility of the government to foster this cooperation by identifying rights, benefits, and duties of each stakeholder in the solid waste management system. In fact, the public–private-community partnership is crucial to improve the sustainable solid waste management in Palestine (Saadeh et al., 2019).

Conclusions and recommendations

Recovery and recycling are considered the best environmentally-friendly practices and of the most important strategies for the management of solid waste, in particular the plastic waste (PW). The application of PW recovery and recycling contributes to sustainable manufacturing by diverting raw plastic materials bearing financial value from the waste and converting it into secondary raw materials. Conservation of valuable natural resources and development in waste management are the primal benefits to promote PW recovery and recycling practices. Although recently there is an increase in the rate of recovery and recycling of PW worldwide, the issue of PW recovery and recycling is remaining a major challenge especially in the developing countries such as Palestine. Several technological, economical, legal, or social attitudes and challenges are still threatening the PW recovery and recycling industry.

In Palestine, there is still a big gap between PW management policies and strategies and the on ground management practices. Therefore, this study analyzed some of the crucial strategies in the recovery and recycling of PW from the perspective of 30

plastic manufacturing and/or recycling companies in the West Bank. These strategies will contribute in achieving sustainable manufacturing and resource utilization of PW in the West Bank. Developing and implementing community awareness programs on PW recovery and recycling is a socially inspired strategy that was ranked higher than others, affecting every aspect for Palestinians. Since the study focused on presenting the perspectives of local companies, most of them agreed that there is an imperative need to update legislations in order to improve PW recovery and recycling in the local environment.

To this direction, Palestinian national strategy of solid waste management needs to be updated to indicate the proposed strategies and monitor their outcomes timely and appropriately. In terms of technological and environmental aspects, the plastic companies strongly support the introduction of new technologies for PW recovery and recycling. Keeping a high demand of recovered and recycled PW in manufacturing is considered an important economic strategy that could benefit manufacturing and/or recycling companies and support the implementation of sustainable recovery and recycling schemes at the country level. The roles of communities and households should not be neglected, as they constitute a cornerstone for a successful operation of PW recovery and recycling schemes. Key players in the solid waste management sector need to be encouraged by local authorities in order to reach a win–win situation in which available resources are fully utilized and environmental health is sustainably promoted and legislatively protected.

Data Availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests The authors declare no competing interests.

References

Alhazmi, H., Almansour, F. H., & Aldhafeeri, Z. (2021). Plastic waste management: A review of existing life cycle assessment studies. *Sustainability, 13*(10), 5340. https://doi.org/10.3390/su13105340

Al-Khatib, I. A., & Al-Sari', M. I., & Kontogianni, S. (2020). Scavengers' contribution in solid waste management sector in Gaza Strip. *Palestine. Environmental Monitoring and Assessment, 192*, 354. https://doi.org/10.1007/s10661-020-08341-y

Al-Khatib, I. A., Monou, M., Abu Zahra, A. S. F., Shaheen, H. Q., & Kassinos, D. (2010). Solid waste characterization, quantification and management practices in developing countries. *A case study: Nablus district - Palestine. Journal of Environmental Management, 91*(5), 1131–1138. https://doi.org/10.1016/j.jenvman.2010.01.003

Al-Salem, S. M., Lettieri, P., & Baeyens, J. (2009). Recycling and recovery routes of plastic solid waste (PSW): A review. *Waste Management, 29*, 2625–2643. https://doi.org/10.1016/j.wasman.2009.06.004

Anayah, F. M., Al-Khatib, I. A., & Hashlamoun, M. W. (2021). Waste electrical and electronic equipment management: A case study in Hebron district, Palestine (Chapter 10). In: D. M. Tirado, B. I. Molina (Eds.). *Public-Private Partnerships: Trends, Perspectives and Opportunities*. Nova Science Publishers, NY, USA. https://doi.org/10.52305/EXYV3481

Baran, B. (2022). Resource (in)efficiency in the EU: A case of plastic waste. *Economics and Law, 21*(1), 45–62. https://doi.org/10.12775/EiP.2022.003

Başaran, B. (2012). What makes manufacturing companies more desirous of recycling? *Management of Environmental Quality: An International Journal, 24*(1), 107–122. https://doi.org/10.1108/14777831311291177

Benson, N. U., Bassey, D. E., & Palanisami, T. (2021). COVID pollution: Impact of COVID-19 pandemic on global plastic waste footprint. *Heliyon, 7*, e06343. https://doi.org/10.1016/j.heliyon.2021.e06343

Brems, A., Baeyens, J., & Dewil, R. (2012). Recycling and recovery of post-consumer plastic solid waste in a European context. *Thermal Science, 16*(3), 669–685. https://doi.org/10.2298/TSCI120111121B

Chamas, A., Moon, H., Zheng, J., Qiu, Y., Tabassum, T., Jang, J. H., Abu-Omar, M., Scott, S. L., & Suh, S. (2020). Degradation rates of plastics in the environment. *ACS Sustainable Chemistry and Engineering, 8*(9), 3494–3511. https://doi.org/10.1021/acssuschemeng.9b06635

Chitaka, T. Y., Russo, V., & Von Blottnitz, H. (2020). In pursuit of environmentally friendly straws: A comparative life cycle assessment of five straw material options in South Africa. *International Journal of Life Cycle Assessment, 25*, 1818–1832. https://doi.org/10.1007/s11367-020-01786-w

DiStefano, C., Shi, D., & Morgan, G. B. (2020). Collapsing categories is often more advantageous than modeling sparse data: Investigations in the CFA framework. *Structural Equation Modeling: A Multidisciplinary Journal.* https://doi.org/10.1080/10705511.2020.1803073

Dweik, H. (2021). The plastic industry worldwide and in Palestine. *Al-Quds Journal for Academic Research, 1*(1), 5. https://doi.org/10.47874/2021p9

European Union (2018). *Behavioural study on consumers' engagement in the circular economy - Final report*. Publications Office of the European Union. https://commission.europa.eu/system/files/2018-10/ec_circular_economy_final_report_0.pdf

Gu, F., Guo, J., Zhang, W., Summers, P. A., & Hall, P. (2017). From waste plastics to industrial raw materials: A life cycle assessment of mechanical plastic recycling practice based on a real-world case study. *Science of the Total Environment, 601–602*, 1192–1207. https://doi.org/10.1016/j.scitotenv.2017.05.278

Hopewell, J., Dvorak, R., & Kosior, E. (2009). Plastics recycling: Challenges and opportunities. *Philosophical Transactions of the Royal Society of London B: Biological Sciences, 364*(1526), 2115–2126. https://doi.org/10.1098/rstb.2008.0311

Hossain, S., Rahman, M. A., Chowdhury, M. A., & Mohonta, S. K. (2021). Plastic pollution in Bangladesh: A review on current status emphasizing the impacts on environment and public health. *Environmental Engineering Research, 26*(6), 200535. https://doi.org/10.4491/eer.2020.535

Jeong, H.-J., & Lee, W.-C. (2016). The level of collapse we are allowed: Comparison of different response scales in safety attitudes questionnaire. *Biometrics & International Journal, 4*(4), 128–134. https://doi.org/10.15406/bbij.2016.04.00100

Kumar, R., Verma, A., Shome, A., Sinha, R., Sinha, S., Jha, P. K., Kumar, R., Kumar, P., & Shubham; Das, S., Sharma, P. & Vara Prasad, P. V. (2021). Impacts of plastic pollution on ecosystem services, sustainable development goals, and need to focus on circular economy and policy interventions. *Sustainability, 13*(17), 9963. https://doi.org/10.3390/su13179963

Lopez, G., Artetxe, M., Amutio, M., Bilbao, J., & Olazar, M. (2017). Thermochemical routes for the valorization of waste polyolefinic plastics to produce fuels and chemicals. A review. *Renewable and Sustainable Energy Reviews, 73*(C), 346–368. https://doi.org/10.1016/j.rser.2017.01.142

Mehta, N., Cunningham, E., Roy, D., Cathcart, A., Dempster, M., Berry, E., & Smyth, B. M. (2021). Exploring perceptions of environmental professionals, plastic processors, students and consumers of bio-based plastics: Informing the development of the sector. *Sustainable Production and Consumption, 26*, 574–587. https://doi.org/10.1016/j.spc.2020.12.015

Mwanza, B. G., & Mbohwa, C. (2017). Drivers to sustainable plastic solid waste recycling: A review. *Procedia Manufacturing, 8*, 649–656. https://doi.org/10.1016/j.promfg.2017.02.083

Mwanza, B. G., Mbohwa, C., & Telukdarie, A. (2018). Strategies for the recovery and recycling of plastic solid waste (PWS): A focus on plastic manufacturing companies. *Procedia Manufacturing, 21*, 686–693. https://doi.org/10.1016/j.promfg.2018.02.172

Napper, I. E., & Thompson, R. C. (2020). Plastic debris in the marine environment: History and future challenges. *Global Challenges, 4*, 1900081. https://doi.org/10.1002/gch2.201900081

Ncube, L. K., Ude, A. U., Ogunmuyiwa, E. N., Zulkifli, R., & Beas, I. N. (2021). An overview of plastic waste generation and management in food packaging industries. *Recycling, 6*(1), 12. https://doi.org/10.3390/recycling6010012

Perugini, F., Mastellone, M. L., & Arena, U. (2005). A life cycle assessment of mechanical and feedstock recycling options for management of plastic packaging wastes. *Environmental Progress, 24*(2), 137–154. https://doi.org/10.1002/ep.10078

PlasticsEurope (2019). *Plastics - The facts 2019: An analysis of European plastics production, demand and waste data*. PlasticsEurope. https://plasticseurope.org/wp-content/uploads/2021/10/2019-Plastics-the-facts.pdf

Saadeh, D., Al-Khatib, I. A., & Kontogianni, S. (2019). Public–private partnership in solid waste management sector in the West Bank of Palestine. *Environmental Monitoring and Assessment, 191*, 243. https://doi.org/10.1007/s10661-019-7395-2

Schlueter, R. (2017). *Solid waste management in the developing world: The role of local government in Kisumu, Kenya*. Independent Study Project Collection, 2654. Retrieved October 21, 2021, from https://digitalcollections.sit.edu/isp_collection/2654

Shen, M., Huang, W., Chen, M., Song, B., Zeng, G., & Zhang, Y. (2020). (Micro)plastic crisis: Un-ignorable contribution to global greenhouse gas emissions and climate change. *Journal of Cleaner Production, 254*, 120138. https://doi.org/10.1016/j.jclepro.2020.120138

Sukholthaman, P., Shirahada, K., & Sharp, A. (2017). Toward effective multi-sector partnership: A case of municipal solid waste management service provision in Bangkok. *Thailand. Kasetsart Journal of Social Sciences, 38*(3), 324–330. https://doi.org/10.1016/j.kjss.2017.05.004

Sweepnet (2014). *Country report on the solid waste management in occupied Palestinian territories*. Sweepnet. https://www.retechgermany.net/fileadmin/retech/05_mediathek/laenderinformationen/Palaestina_RA_ANG_WEB_Laenderprofile_sweep_net.pdf

Thoni, V., & Matar, S. (2019). *Solid waste management in the occupied Palestinian territory: West Bank including East Jerusalem and Gaza Strip*. CESVI. https://www.cesvi.eu/wp-content/uploads/2019/12/SWM-in-Palestine-report-Thoni-and-Matar-2019_compressed-1.pdf

Timbrook, J., Smyth, J., & Olson, K. (2021). Are self-description scales better than agree/disagree scales? *International Journal of Market Research, 63*(2), 201–215. https://doi.org/10.1177/1470785320971592

Zheng, J., & Suh, S. (2019). Strategies to reduce the global carbon footprint of plastics. *Nature Climate Change, 9*(5), 374–378. https://doi.org/10.1038/s41558-019-0459-z