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CHALLENGES AND SOLUTIONS FOR EXTENDED PRODUCER RESPONSIBILITY IN EGYPT

Mohamed Sayed[1,*], Sherien Elagroudy[2], Abdallah Nassour[3]

[1] Department of Civil Engineering, Faculty of Engineering, Heliopolis University, Cairo, Egypt,

[2] Egypt Solid Waste Management Center of Excellence, Faculty of Engineering, Ain Shams University, Cairo,

[3] Department of Waste and Resource Management, Rostock University, 18051 Rostock, Germany

***Correspondence:** mohammed.sayed@hu.edu.eg

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ABSTRACT

This paper explores the challenges and proposes solutions for implementing Extended Producer Responsibility (EPR) in Egypt, with a particular focus on managing plastic waste. Egypt spends a significant portion of its annual budget on waste management, which places a considerable strain on its financial system. The implementation of EPR faces several obstacles, including inadequate infrastructure, limited resources, and weak regulatory frameworks, coupled with insufficient coordination among stakeholders. The study emphasizes the importance of integrating both formal and informal waste collectors, such as the Zabbaleen, to enhance the efficiency of waste management. The research methodology involved conducting case studies on both developed and developing countries to understand the application of EPR and identify best practices. Moreover, interviews were conducted with key stakeholders in Egypt to gather insights on current challenges and potential solutions. The paper also discusses government initiatives, including the 2017 pilot project aimed at incentivizing recycling, which faced resistance from private garbage collectors. By addressing these challenges and fostering collaboration among diverse stakeholders, the paper proposes a framework that visually maps out the connections between different stakeholders to facilitate effective EPR implementation in Egypt. The findings underscore the importance of clear stakeholder coordination and engagement to ensure a sustainable and successful EPR system that benefits both the environment and the economy.

KEYWORDS: Extended Producer Responsibility, EPR, Solid Waste, Municipal Solid Waste Management, Circular Economy.

التحديات والحلول المتعلقة بمسؤولية المنتج الممتدة في مصر

محمد سيد[1,*]، شيرين العجرودي[2]، عبد الله ناصور[3]

[1*] قسم الهندسة المدنية، كلية الهندسة، جامعة هليوبوليس، القاهرة، مصر.

[2] مركز مصر المتميز لإدارة المخلفات الصلبة، كلية الهندسة، جامعة عين شمس، القاهرة.

[3] قسم إدارة النفايات والموارد، جامعة روستوك، 18051 روستوك، ألمانيا.

***البريد الاليكتروني للباحث الرئيسي :** mohammed.sayed@hu.edu.eg

الملخص

تستكشف هذه الورقة التحديات وتقترح الحلول لتطبيق نظام المسؤولية الممتدة للمنتِج (EPR) في مصر، مع التركيز بشكل خاص على إدارة النفايات البلاستيكية. تنفق مصر جزءًا كبيرًا من ميزانيتها السنوية على إدارة النفايات، مما يشكل ضغطًا كبيرًا على نظامها المالي. يواجه تطبيق نظام المسؤولية الممتدة للمنتِج عدة عقبات، بما في ذلك البنية التحتية غير الكافية، والموارد المحدودة، والأطر التنظيمية الضعيفة، إلى جانب التنسيق غير الكافي بين أصحاب المصلحة. وتؤكد الدراسة على أهمية دمج جامعي النفايات الرسميين وغير الرسميين، مثل الزبالين، لتعزيز كفاءة إدارة النفايات. اعتمدت منهجية البحث على إجراء دراسات حالة لبلدان

متقدمة ونامية لفهم تطبيق نظام المسؤولية الممتدة للمنتِج وتحديد أفضل الممارسات. بالإضافة إلى ذلك، أُجريت مقابلات مع أصحاب المصلحة الرئيسيين في مصر لجمع رؤى حول التحديات الحالية والحلول المحتملة. كما تناقش الورقة المبادرات الحكومية، بما في ذلك مشروع تجريبي في عام 2017 يهدف إلى تحفيز إعادة التدوير، والذي واجه مقاومة من قبل جامعي النفايات الخاصين. من خلال معالجة هذه التحديات وتعزيز التعاون بين مختلف أصحاب المصلحة، تقترح الورقة إطارًا يوضح بشكل مرئي الروابط بين مختلف أصحاب المصلحة لتسهيل تنفيذ نظام المسؤولية الممتدة للمنتِج بشكل فعّال في مصر. وتؤكد النتائج على أهمية التنسيق الواضح ومشاركة أصحاب المصلحة لضمان نظام مسؤولية ممتدة مستدام وناجح يعود بالفائدة على البيئة والاقتصاد.

الكلمات المفتاحية : مسؤولية المنتج الممتدة، النفايات الصلبة، إدارة النفايات الصلبة البلدية، الاقتصاد الدائري.

1. Introduction

Extended Producer Responsibility (EPR) is a concept in which manufacturers are held responsible for the environmental impact of their products throughout the entire lifecycle of the product, including disposal or recycling [1, 2]. In Egypt, EPR is not yet fully implemented, but there have been efforts to increase awareness and adoption of the concept. In 2020, the Egyptian's policymakers adopted the low No.202 of 2020 to the organize and manage waste management, which contains in its article 17 the foundation of EPR in Egypt.

The Fast-Moving Consumer Goods (FMCG) sector in Egypt plays a significant role in the country's economy. With a growing market projected to exceed $1 million in profit and supporting over 117,800 workers. The FMCG industry is committed to resource efficiency and environmental responsibility through waste management practices, sustainable product design, and community engagement. These insights into the FMCG sector's waste management systems, wastewater treatment, and partnerships with waste collectors highlight the industry's dedication to achieving sustainability milestones.

Due to the rapid growth population in Egypt, the municipal solid waste rate has increased brutally. The master plans prepared for the governorates indicated that the total generation of municipal waste in the Arab Republic of Egypt amounted to approximately 27.6 million tons annually for the year 2019, out of which approximately one third is estimated to be packaging waste [3]. The per capita waste generation rate ranges between 0.75 - 1.25 kg/day, and the annual waste generation rate increases by approximately 4%. The figure below illustrates the population and the estimated amount of waste in the Arab Republic of Egypt from 2017 to 2019 [4].

Consequently, the rate of the packaging waste has increased notably such as plastic, paper, etc. In this paper, the study will focus on the plastic waste that has damage on the environment. This made Egypt in seventh place out of 192 countries in terms of the volume of marine plastic waste[5]. Egypt consumes high rate of expenses annually in order to manage the produced waste, which affect negatively on the financial system of the country [6].

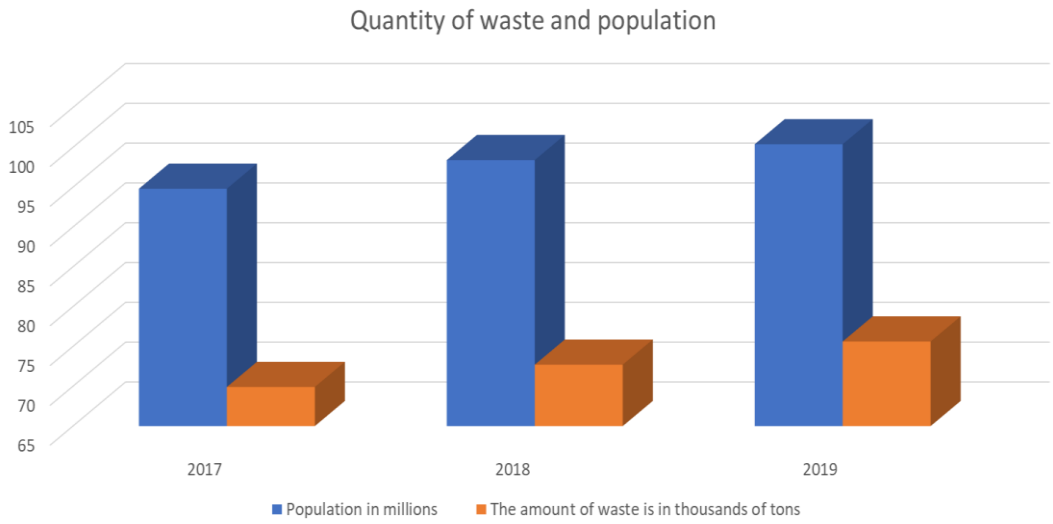

Figure (1) Population census and quantity of waste from 2017 to 2019 [4].

In designing a practical and functional EPR system for Egypt, several key parameters must be addressed and understood, including the markets at play at the product, waste stream, and (recycled) raw material levels; the characteristics of the territory in terms of geography, demography, economics, and infrastructure; the stakeholders involved and their expectations and potential roles and responsibilities; the targets to be achieved, in terms of being quantifiable, realistic, and ambitious, with defined timelines for achievement, and whether they are indicative or mandatory and collectively set or individually; the legal framework necessary to make the EPR objectives enforceable; the regime of incentives and penalties that will support enforcement; and the licensing process for the Producer Responsibility Organization (PRO) responsible for the implementation and management of the scheme, if applicable [7].

The implementation of EPR in Egypt faces several challenges, including the lack of infrastructure and resources for proper waste collection and disposal, as well as the absence of effective regulations and enforcement mechanisms in order to ensure that manufacturers take responsibility for their products. Moreover, the lack of coordination and cooperation among different stakeholders such as government agencies, the private and public sectors, and civil society organizations, is another significant obstacle to the successful implementation of EPR in the Egyptian context.

To address these challenges, in 2020, the policy makers in Egypt adopted a new law – Law No. 202 of 2020 – which aims to organize and manage waste management in the country [8]. This Law establishes a general framework for planning and preparing waste management strategies, including the implementation of an EPR policy to deal with specific waste streams. The law also defines clear roles and responsibilities, ensures sustainable financial resources, provides incentives for investment in the waste management sector, and integrates both formal and informal waste workers into the system, as elaborated in the published report by the Ministry of Environment [9].

Thus, new solutions must be found and put into action in order to preserve the environment from waste, in addition to applying an economic mechanism to finance the solid waste management system [10]. Not to mention that the execution of the Law No.202 of 2020 will be of great added value as it focuses on applying the concept of EPR for the safe disposal of resulting waste [8].

This research paper, therefore, aims to examine the challenges and solutions for applying the concept of EPR in Egypt, and how to coordinate and cooperate among various stakeholders.

Moreover, this paper elaborates on the successful selected examples of EPR models that have been adopted in different countries in order to give producers responsibility for managing their own products from the early until the post-consumer stage.

2. Extended Producer Responsibility

The implementation of an Extended Producer Responsibility (EPR) scheme in Egypt can have multiple effects, and it is crucial to define the specific objectives pursued with this initiative [7]. The potential EPR objectives include reducing and avoiding landfilling, preventing waste, organizing waste collection and treatment, reducing waste fees for citizens, ensuring the financing of waste collection and treatment, preventing littering, reducing the use of resources and virgin materials, increasing recycling and supporting closed-loop approaches, and ultimately reducing the environmental impact of producers. The selection of the specific objectives will significantly impact the design and implementation of the EPR scheme, ensuring that it effectively addresses the identified challenges and achieves the desired outcomes [7, 11, 12].

Egypt has set ambitious sustainability goals, aiming to achieve zero manufacturing waste to landfill by 2030 through waste segregation, recycling, and reuse programs. The country also plans to reduce carbon emissions by 50% by 2030 by implementing energy-efficient technologies, transitioning to renewable energy, and optimizing production processes. To support these objectives, Egypt is investing in community engagement, environmental education, regulatory compliance, and obtaining relevant certifications like ISO 14001 and ISO 45001. Additionally, the country is implementing Extended Producer Responsibility (EPR) systems and developing rigorous monitoring mechanisms to drive continuous improvement in waste management. This comprehensive sustainability roadmap provides important context for the research on EPR implementation in Egypt and highlights the country's commitment to transforming its waste management landscape [13, 14].

In 2017, the Egyptian government launched the “Sell Your Garbage” initiative in an attempt to promote recycling and reduce waste in Cairo. The project, marketed heavily on social media and mainstream media, opened two collection kiosks in the middle and upper-class district of Heliopolis. The initiative offered cash payments to citizens who brought in sorted recyclable materials, with the prices varying daily based on the informal recycling and scrap market [15, 16]. While the government, media, and some citizens reacted positively to the project, it faced strong rejection from Egypt's traditional garbage collectors, known as the Zabbaleen. The Zabbaleen, who had long been the backbone of Cairo’s informal waste management system, saw their incomes drop significantly from five bags of cans and plastics collected daily to just two. This led to criticism from Shehata Meqadas, the head of the Zabbaleen syndicate, who argued that the project had left some garbage collectors jobless. Despite this, the project founders continued, describing the project as a step towards greener economic policies and better waste management in Egypt [15, 16].

This initiative was not the first time the government had attempted to modernize Cairo's waste management system [15, 16]. In 2003, The government awarded contracts to European companies to handle waste, but this failed to compete with the Zabbaleen's established system. In 2009, the government went as far as slaughtering around 350,000 waste-fed pigs, which had helped the Zabbaleen reduce waste and provided them with an important source of income. The whole process was elaborated through an article featured by Al-Ahram online [17]. In line with Bowers in her published work [18], these actions highlight the recurring gap between the government’s

waste management initiatives and the needs and interests of key. Therefore, the government is recommended to adopt a more inclusive approach, partnering with the Zabbaleen and other stakeholders, to achieve the best results in improving waste management in Egypt.

A notable step towards addressing these challenges was the establishment of the Waste Management Regulatory Authority (WMRA) by Prime Minister's Decree No. 3005 in 2015. WMRA is tasked with regulating, monitoring, and controlling all aspects of waste management at both the central and regional levels, aiming to improve the environment-friendly management of all types of waste. The agency is also responsible for coordinating the development of the waste management sector, implementing policies, plans, and programs, and providing technical assistance to authorities managing various waste streams [19]. By fostering a more inclusive approach, including working closely with the Zabbaleen community, the WMRA could enhance the efficiency and sustainability of waste management systems in Egypt, benefiting all stakeholders involved. This would be a critical step in addressing the challenges and implementing effective EPR policies to promote a circular economy and reduce the environmental impact of waste in the country [20, 22].

Previous scholars have explained in their article [23] how the European Union (EU) has been a leader in implementing EPR policies. Key legislation like the Waste Framework Directive mandates EPR schemes for packaging waste among member states. They also have elaborated on Germany's Packaging Ordinance, established in 1991, which is a notable example, requiring all packaging manufacturers and distributors managing their waste. This led to the creation of the Duales System Deutschland (DSD), significantly boosting recycling rates and establishing Germany as a leader in waste management by 2017.

In Asia, Japan and South Korea have integrated EPR into their waste management systems with notable success. Japan's Home Appliance Recycling Law and South Korea's EPR system cover various products, including electronics and packaging materials. These policies have drastically improved recycling rates and reduced landfill use. For example, by 2015, South Korea achieved a 75% recycling rate for electronics, underscoring the effectiveness of EPR in the region [24, 25].

EPR has been implemented at the state and provincial levels in North America. In Canada, British Columbia's Recycling Regulation mandates producers to manage the lifecycle of products like electronics and packaging. This has led to high recycling rates, particularly for electronics. In the United States, states such as California and Maine have introduced their own EPR programs. California's carpet recycling law has significantly reduced landfill contributions, showcasing the benefits of localized EPR initiatives [26].

In developing countries, EPR is becoming crucial for addressing waste management challenges [27, 28]. India's Plastic Waste Management Rules require producers to create systems for collecting and processing plastic waste, aiming to curb plastic pollution despite enforcement challenges [29]. Indonesia's waste management law also incorporates EPR principles to reduce plastic waste [30, 31]. These efforts highlight the growing importance of EPR in managing waste sustainably in developing regions.

The global trend towards EPR supports the shift towards circular economies, where products are designed for reuse, repair, and recycling [20, 22]. The success of EPR in different regions demonstrates its potential to reduce waste and promote sustainable consumption. Effective EPR schemes rely on strong regulatory frameworks, enforcement, and stakeholder participation [7,

12]. As countries continue to refine their EPR policies, international collaboration and knowledge sharing will be crucial in addressing global waste challenges [32].

Previous scholars, Gupt and Sahay [33], and Johannes et al. [30] stressed on the pressing need of providing EPR in developing countries in order to minimize solid waste in the environment. This was applied as well in other countries such as India, Indonesia, Vietnam…etc. Gupt and Sahay [33] conducted an exploratory review of 27 cases of extended producer responsibility from developed and developing economies with and without informal recycling. This study was done, therefore, in order to ascertain the most important aspect of extended producer responsibility. Johannes et al [30] concluded that in developing countries, the EPR system is mostly implemented for electronic waste. However, with the rising concern on the marine plastic issue, developing countries, including those in Asia, have started to apply EPR for package and container waste, in consistent with the findings of Gupt and Sahay [33].

3. Methodology

In order to achieve the purpose of the study, the research was carried-out in several stages. The first stage involved an in-depth analysis of selected case studies to understand how the Extended Producer Responsibility (EPR) principle is applied in different contexts This stage focused on identifying best practices that could potentially be adapted to the Egyptian context.. Building on these insights, the second stage focused on a detailed case study of Egypt. This involved conducting a stakeholder analysis to map the roles. interests, and potential contributions of various stakeholders, such as government entities, waste management companies, producers/manufacturers, and consumer groups, towards implementing the EPR principle in Egypt. The stakeholder analysis helped identify the key obstacles and challenges faced by Egypt in improving its overall waste management processes.

Moreover, to gain deeper understanding of the waste management landscape, the third stage included a survey with 20 interviews of Fast-Moving Consumer Goods (FMCG) companies operating in Egypt, both with national and international product portfolios. This allowed us to identify waste generation patterns and characteristics within the FMCG sector, explore the current waste management practices, challenges, and needs of FMCG companies, and assess the FMCG companies' awareness and advocacy towards the application of the EPR principle. The insights gathered from the FMCG survey enabled us to provide tailored recommendations to the recycling company on how to effectively expand its client base and align its service offerings to the needs of the FMCG sector.

The research also explored Egypt's broader sustainability roadmap and its implications for waste management and the implementation of the Extended Producer Responsibility (EPR) principle. Finally, the study continued by analyzing the patterns and characteristics of the data to understand the main trends and factors affecting waste management in Egypt. This holistic approach allowed the study to develop a well-rounded understanding of the complexities involved and identify strategic interventions to improve waste management processes in the country.

3.1. Case Studies and Comparative Analysis

To gain positive insights into effective Extended Producer Responsibility (EPR) practices, the methodology involves an in-depth examination of EPR implementation in several countries, both developed and developing, that have demonstrated leadership in this domain. Case study approach is known for its efficiency in exploring and analyzing real-life situations in order to obtain

reliable conclusions [34, 35]. Moreover, a comparative analysis was carried-out between different cases to support the overall study [36].

3.1.1. International Case Studies

Germany: Renowned as a global leader in recycling, Germany's success is attributed to its stringent EPR policies, particularly the 1991 Packaging Ordinance. This mandate requires packaging manufacturers and distributors to fully fund and ensure the recycling and recovery of their waste. The Duales System Deutschland (DSD) facilitates efficient collection and recycling through the innovative Green Dot system, leading to high compliance rates. As a result, Germany was named the world champion recycling country in 2017, with an overall recycling rate of 66.1% for municipal solid waste [23].

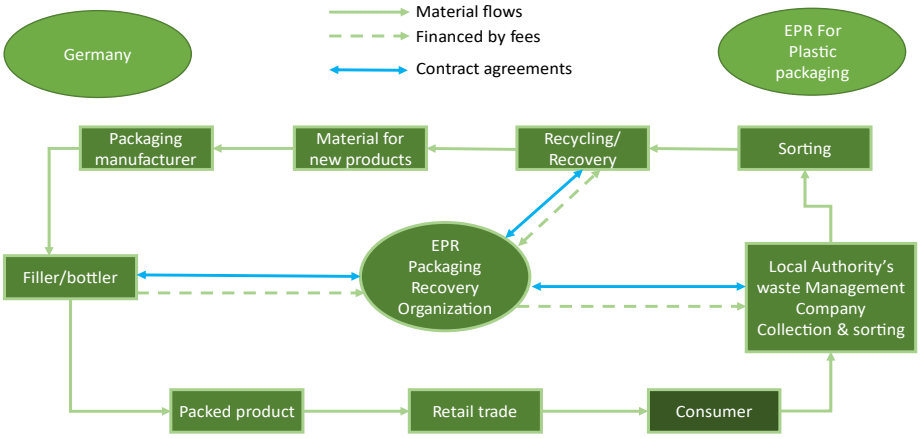

Figure (2) PROs' role within the product and waste management circular process [37].

Spain: Under Law 22/2011, Spain incorporates EPR principles through SCRAP systems covering various waste streams like packaging, batteries, and tires. Waste management strategies are guided by national plans, such as the Integrated Waste Management and Resource Plan (PEMAR), with regional authorities responsible for municipal waste services. Despite some regional disparities, Spain has made significant strides in aligning local waste management with national and European Union targets, achieving a municipal solid waste recycling rate of 35.5% by 2020 [32, 38].

Portugal: Managed by the Portuguese Environment Agency, Portugal's waste management involves the development of specific strategic plans for different waste types. The Sociedade Ponto Verde (SPV) oversees the integrated system for packaging waste management. Through the SIGRE system, stakeholders in the packaging value chain contribute to efficient collection and recycling, leading to improved waste management outcomes. Portugal's municipal solid waste recycling rate reached 31.9% in 2020 [32].

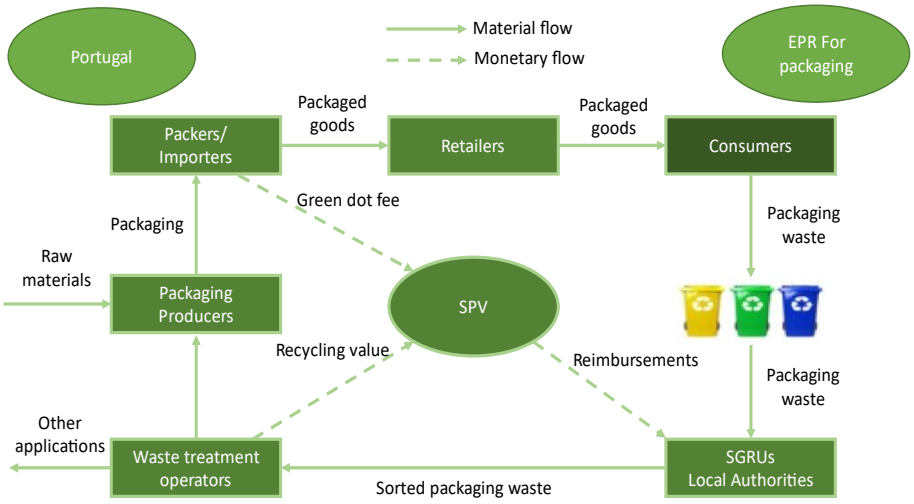

Figure (3) Material and monetary flow of the packaging waste systems [32, 39].

Indonesia: Indonesia's waste management law, supported by regulations like Government Regulation No. 81/2012, emphasizes the 3R concept of reduce, reuse, and recycle [30, 31]. The Indonesia Packaging Recovery Organization (IPRO) focuses on PET bottle recycling, with plans to expand to other materials. Waste banks and junk shops play a crucial role in the collection system, particularly in rural areas. Indonesia's overall recycling rate for municipal solid waste stood at 14.5% as of 2019 [30].

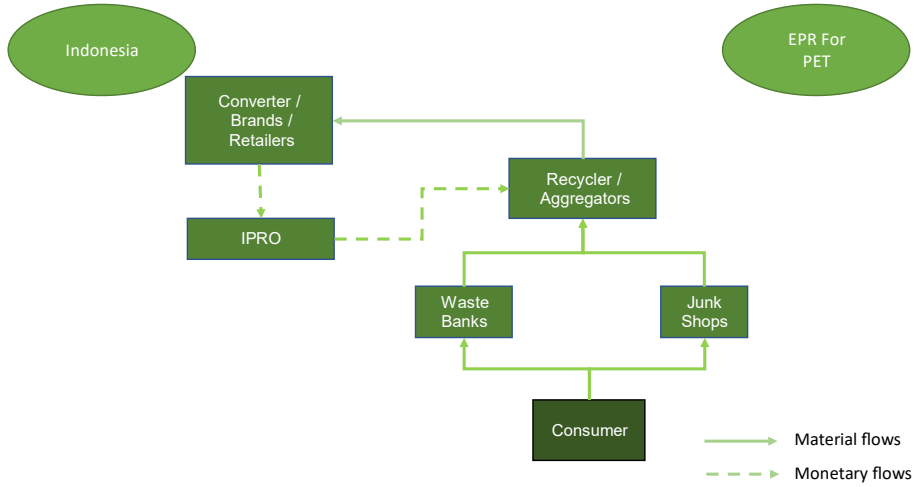

Figure (4) EPR collection system in Indonesia [30].

India: The Plastic Waste Management Rules, introduced in 2011 and revised in 2016 and 2020, mandate EPR for producers, importers, and brand owners. The Unified Framework for EPR, established in 2020, emphasizes the collection and recycling of post-consumer plastic waste. Despite challenges like regulatory clarity and enforcement, India is progressively working towards reducing single-use plastics and improving recycling rates through comprehensive EPR mechanisms. The country's municipal solid waste recycling rate reached 12.5% in 2020 [29].

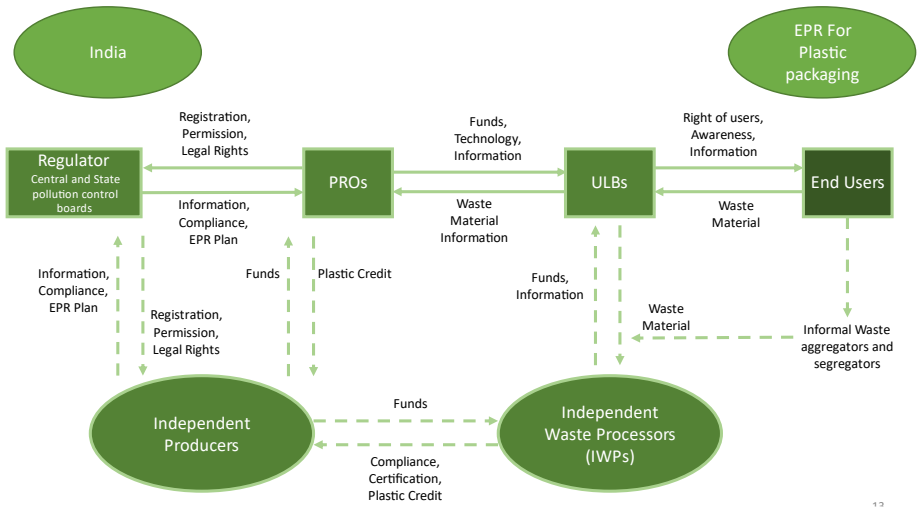

Figure (5) Indian EPR Framework-2020 [29].

3.1.2. Comparative Analysis

Table 1 provides a comparative analysis of the key aspects such as legislative frameworks, stakeholder engagement, effectiveness, and challenges faced by each country. Insights from these case studies can guide the development and refinement of EPR policies in Egypt [23, 29, 30, 32, 37, 39].

Table 1. Comparative Analysis between Selected Case Studies

	Germany	Spain	Portugal	Indonesia	India
Legislative Framework and Regulatory Approach	**Verpackungsverordnung** (Packaging Ordinance)mandates that packaging manufacturers and distributors are fully responsible for the waste they produce. Established the **Duales System Deutschland (DSD)** for collection and recycling of packaging waste, ensuring compliance with recycling targets.	**Law 22/2011** incorporates EPR principles, emphasizing producer responsibility from design through end-of-life management. Utilizes **SCRAP** (EPR Collective Systems) for various waste streams including packaging, batteries, tires, etc. **Regional heterogeneity** with each autonomous community having its waste management plans aligned with national targets.	**Sociedade Ponto Verde (SPV)** manages packaging waste through an integrated system funded by stakeholders in the packaging value chain. Implementation of **SIGRE** for managing urban packaging waste, ensuring collection, recycling, and environmentally friendly disposal.	Introduced a **new waste management law in 2008**, followed by specific regulations such as Government Regulation No. 81 in 2012 and Ministry of Environment Regulation No. 13 in 2012. Focus on **household waste** management and implementation of the **3R** (**Reduce**, **Reuse**, **Recycle**) concept through waste banks. Establishment of the Indonesia **Packaging Recovery**	Introduced the **Plastic Waste** (Management & Handling) Rules in **2011** and revised in **2016** and **2020**. Mandates for State Pollution Control Boards (**SPCBs**), Urban Local Bodies (**ULBs**), and producers/ importers to manage and recycle plastic waste. Evolution towards a **Unified Framework** for EPR in **2020**, emphasizing producer

				Organization (**IPRO**) by the Packaging and Recycling Association for Indonesia Sustainable Environment (**PRAISE**) to manage recycling programs, initially targeting **PET** bottles.	responsibility for collection and recycling of post-consumer plastic waste.
Stakeholder Engagement and Responsibility	Strong involvement of manufacturers and distributors through **DSD** and **Green Dot system**. Producers bear direct financial responsibility for meeting recycling and recovery targets.	Involvement of **various stakeholders** including producers, regional administrations, distributors, and waste management entities. **SCRAP** ensures collective responsibility across different waste streams under EPR.	Collaboration among stakeholders in the packaging value chain (manufacturers, packers, importers) through SPV. **SIGRE** manages responsibilities for urban and industrial packaging waste, promoting recycling and waste reduction.	**IPRO** focuses on a market-based collection system involving waste banks and junk shops, particularly in rural and remote areas. Collaboration with **recyclers**/**aggregators** to establish a **closed-loop** recycling market.	Producers, importers, and brand owners are mandated to develop and implement EPR plans. Flexibility in the approach to waste collection and recycling, either individually or in collaboration with **Urban Local Bodies (ULBs)**. Emphasis on eliminating non-recyclable multilayered plastics and enforcing bans on single-use plastics.
Effectiveness and Achievements	Recognized as a global leader in recycling rates and waste management due to stringent EPR policies. **DSD** system ensures high rates of collection and	Significant regional variations but overall alignment with national waste management targets. **SCRAP** and **local waste management** plans contribute to effective EPR implementation across diverse regions.	**SPV's** management of packaging waste has improved collection rates and recycling efficiency. **SIGRE** ensures comprehensive coverage of packaging	Initial steps towards establishing a robust **EPR** framework through **IPRO** and waste banks. Potential for expanding recycling initiatives beyond PET bottles	Progress towards **reducing reliance** on **single-use** plastics through legislative bans and comprehensive EPR frameworks.

	recycling compliance.		waste from urban and industrial sectors.	to other packaging materials.	Continued adaptation and enforcement needed to achieve national goals of plastic waste reduction and recycling.
Challenges and Adaptation	Continuous adaptation to meet evolving recycling and environmental targets. Balancing industry compliance with consumer and environmental expectations.	Managing regional disparities in waste management infrastructure and capabilities. Ensuring uniform application of EPR principles across autonomous communities.	Addressing challenges in integrating regional waste management strategies under a national framework. Enhancing collaboration among stakeholders to improve waste prevention and recycling efforts.	Challenges include scaling up waste management infrastructure in urban and rural areas. Integration of informal waste sector (waste banks, junk shops) into formal recycling systems.	Initial challenges with clarity on responsibilities among stakeholders in the plastic waste value chain. Transitioning from sporadic measures to a unified EPR framework to improve effectiveness and enforcement. Diverse regional contexts necessitate adaptable EPR mechanisms to suit local conditions.

3.2. Stakeholder Analysis in Egypt

By involving and aligning diverse stakeholders as shown in table 2, EPR implementation in Egypt can be more effective and inclusive. This approach ensures sustainable waste management and environmental protection by encouraging collaboration among government bodies, private sector entities, NGOs, and local communities. The analysis underscores the importance of collaboration among government agencies, the private sector, civil society organizations, and the informal sector to achieve effective EPR implementation, compiled from [7, 40, 42].

To better understand the challenges and opportunities of implementing EPR in Egypt, this section compares EPR frameworks in five countries: Germany, Spain, Portugal, Indonesia, and India. These countries represent diverse approaches and varying success levels in EPR, offering valuable lessons for Egypt.

Table 2. Stakeholder Analysis in Egypt

		Roles	Interests	Potential Contributions
Government Agencies	**Ministry of Environment**	Policy-making, regulation, oversight of EPR implementation, and environmental protection.	Ensuring effective waste management, reducing environmental pollution, and promoting sustainable practices.	Developing and enforcing EPR regulations, providing guidelines and support for implementation, and monitoring compliance.
	Local Municipalities	Local enforcement of waste management policies, collection and disposal of municipal waste, and public awareness campaigns.	Maintaining clean and healthy urban environments, reducing waste management costs, and enhancing local recycling rates.	Implementing EPR programs at the local level, coordinating with waste management companies, and engaging the community.
	Ministry of Finance	Budget allocation, financial incentives for waste management, and taxation policies.	Optimizing budget use, supporting economic growth through green initiatives, and ensuring financial sustainability of EPR programs.	Providing funding and financial incentives for EPR initiatives, tax benefits for compliant businesses, and economic analysis of EPR impact.
	Ministry of Industry and Trade	Regulating manufacturing processes, ensuring compliance with EPR, and supporting industrial sustainability.	Promoting sustainable industrial practices, reducing waste generation, and fostering innovation in recycling technologies.	Enforcing EPR regulations in the manufacturing sector, facilitating industry collaborations, and promoting eco-friendly product designs.
Private Sector	**Manufacturers**	Designing, producing, and distributing products with EPR compliance.	Reducing waste management costs, enhancing corporate social responsibility, and improving brand image.	Implementing take-back schemes, redesigning products for easier recycling, and financing recycling programs.
	Waste Management Companies	Collection, transportation, recycling, and disposal of waste.	Expanding business opportunities, improving operational efficiency, and increasing recycling rates.	Providing infrastructure and services for EPR programs, collaborating with manufacturers and municipalities, and investing in recycling technologies.
	Retailers	Selling products and participating in take-	Enhancing customer loyalty, reducing waste disposal costs,	Facilitating in-store take-back programs, educating consumers

		back and recycling programs.	and supporting sustainable practices.	about recycling, and collaborating with manufacturers on sustainable packaging.
Civil Society Organizations	**Non-Governmental Organizations (NGOs)**	Advocacy, education, and program implementation for waste management and recycling.	Promoting environmental sustainability, raising public awareness, and influencing policy decisions.	Conducting awareness campaigns, providing technical expertise, and monitoring EPR program effectiveness.
	Community Groups	Local engagement and participation in recycling initiatives.	Improving community health and environment, reducing local waste, and fostering community cohesion.	Organizing local recycling drives, educating residents, and collaborating with municipalities and NGOs.
	Academic and Research Institutions	Conducting research, providing data, and supporting policy development.	Advancing scientific understanding of waste management, influencing policy through evidence-based research, and promoting innovation.	Providing research and data to support EPR policies, developing new recycling technologies, and evaluating program outcomes.
Informal Sector Workers	**Waste Pickers (Zabbaleen)**	Collecting and sorting recyclable materials from waste.	Securing livelihoods, improving working conditions, and gaining recognition and support.	Enhancing recycling rates through efficient waste sorting, providing valuable insights into the informal waste sector, and collaborating with formal waste management systems.
	Recyclers	Processing and selling recyclable materials.	Increasing income, improving operational efficiency, and expanding market access.	Converting collected recyclables into marketable materials, supplying raw materials for manufacturing, and reducing the burden on landfills.
	Scrap Dealers	Buying recyclable materials from waste pickers and selling them to recycling companies.	Maximizing profits, securing a steady supply of recyclables, and ensuring fair trade practices.	Facilitating the flow of recyclable materials within the market, providing financial support to waste pickers, and ensuring the sustainability of the recycling chain.

4. Results and Discussion

The implementation of Extended Producer Responsibility (EPR) in Egypt presents a complex web of interactions among diverse stakeholders, each playing a pivotal role in the nation's waste management ecosystem. The Ministry of Environment, through the Waste Management Regulatory Authority (WMRA), serves as the central regulatory body overseeing EPR compliance.

The Ministry's responsibilities include registering producers, granting permissions, and formulating the EPR plan. Additionally, it ensures that independent producers and Producer Responsibility Organizations (PROs) comply with legal and environmental standards. However, challenges such as inconsistent compliance and bureaucratic delays often hinder the Ministry's effectiveness. By enhancing its data collection and analysis capabilities, the Ministry can make more informed decisions and adjustments to EPR policies, thereby improving its regulatory impact.

Producer Responsibility Organizations (PROs) are essential to the financial and operational management of EPR. They act as intermediaries, facilitating fund allocation, ensuring compliance, and connecting regulatory bodies with operational entities such as municipalities and recyclers. However, the success of PROs in Egypt hinges on their ability to manage funds transparently and maintain trust among stakeholders. Challenges such as potential conflicts of interest and the need for transparency can be mitigated by implementing periodic audits and public reporting, which would enhance accountability and foster greater cooperation within the EPR framework.

Municipalities (Governorates) are at the forefront of waste collection and public engagement. They play a vital role in disseminating information to the public, providing technological support, and ensuring the collection and proper disposal of waste. Despite their critical role, many municipalities face challenges due to limited resources and technological capabilities. Addressing these gaps through capacity-building initiatives and increased funding could significantly improve the effectiveness of EPR implementation at the local level. Municipalities are also essential in bridging the gap between consumers and the formal waste management sector, highlighting the importance of strengthening their operational capabilities.

Consumers as generators of waste, are integral to the success of EPR. Their participation in recycling initiatives and waste segregation is crucial. However, low levels of awareness and engagement pose significant challenges. Public awareness campaigns tailored to different demographic groups could significantly improve consumer behavior and participation in EPR efforts. Educating consumers about the environmental impact of waste and their role in the EPR system is essential for fostering a culture of recycling and responsible waste disposal.

Informal Sector particularly waste pickers and Segregators, plays a vital role in collecting and sorting recyclable materials. Despite their significant contributions, they often operate without formal recognition or support, limiting their potential and exposing them to economic and social vulnerabilities. Integrating the informal sector into the formal waste management framework through legal recognition, training programs, and financial support could enhance recycling rates and improve the livelihoods of those involved. This integration would also contribute to the overall effectiveness of the EPR system by leveraging the strengths of both formal and informal waste management systems.

Independent Producers are responsible for complying with EPR regulations and funding PROs. Their participation is critical to the financial sustainability of the EPR system. However, navigating complex regulatory requirements and securing the necessary funds for compliance can be challenging. Providing financial incentives, such as tax breaks or grants, alongside clearer

guidelines, could improve compliance rates and encourage more active participation from producers.

Waste Recyclers including those producing Refuse-Derived Fuel (RDF), play a crucial role in transforming waste materials into usable products. Their success depends on a consistent supply of quality materials from both the formal and informal sectors. However, challenges such as inconsistent material supply and limited access to advanced recycling technologies can hinder their effectiveness. Investing in modern recycling technologies and strengthening partnerships with waste collection entities could improve the efficiency of recycling operations, contributing to the overall success of EPR in Egypt.

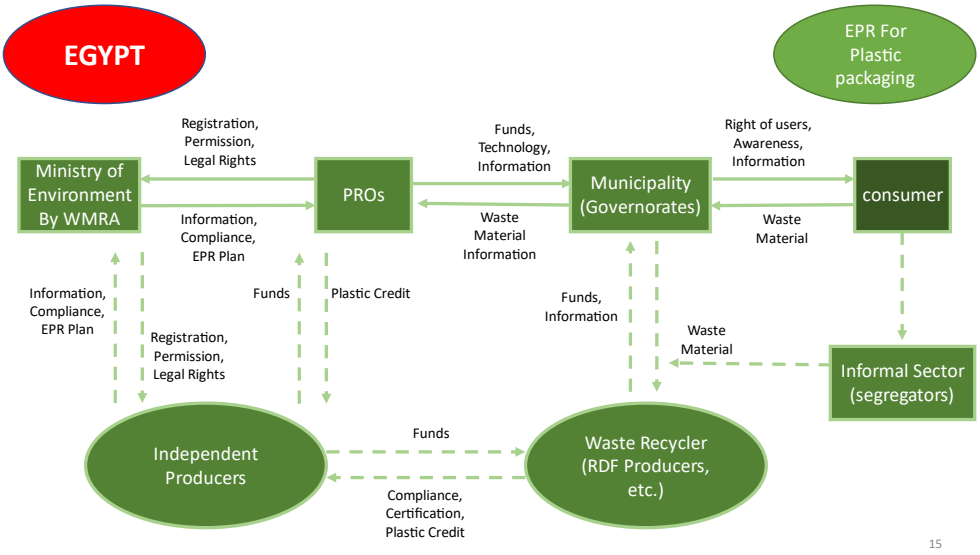

Figure (6) Stakeholder Interactions in EPR for Plastic Packaging in Egypt.

The interactions among these stakeholders are visualized in Figure (6), which highlights the flow of information, funds, and materials within the EPR system. The diagram highlights the multi-faceted interactions among stakeholders in the EPR framework. Each entity contributes to the overall goal of sustainable waste management and recycling, ensuring that responsibilities are distributed across the network. For example, the Ministry of Environment plays a central role in regulatory oversight and compliance, while PROs facilitate the financial and operational aspects of EPR. Municipalities act as the bridge between consumers and the formal waste management sector, and the informal sector plays a crucial role in waste collection and segregation.

By understanding these interactions and roles, we can identify areas for improved coordination and cooperation, ensuring a more effective implementation of EPR in Egypt. The visits and surveys conducted as part of this research on EPR implementation in Egypt revealed several critical areas that waste management service providers must address to become successful partners for FMCG companies. Ensuring legal compliance, obtaining relevant certifications like ISO 14001 and ISO 45001, and maintaining up-to-date knowledge of environmental regulations are essential to building trust and credibility. Investing in modern waste management infrastructure and advanced technologies, such as digital tracking systems and smart bins, can also enhance operational efficiency and reliability. Establishing a strong track record through consistent service delivery, client testimonials, and transparent performance metrics is crucial for demonstrating capabilities. Further, rigorous data collection, regular audits, and detailed reporting further

demonstrate a commitment to continuous improvement and environmental responsibility. Crucially, the research also found that most of the interviewees were not aware of any existing EPR systems in Egypt, highlighting the need for greater awareness and engagement with these programs. By addressing these key areas, waste management service providers can position themselves as valued partners in Egypt's comprehensive sustainability agenda and contribute to the country's ambitious waste reduction and recycling goals.

To enhance the effectiveness of EPR implementation in Egypt, several recommendations can be made. First, Enhancing coordination between the Ministry of Environment, PROs, and municipalities is crucial. Strengthening communication channels through regular inter-agency meetings and shared digital platforms for data exchange would facilitate cohesive implementation of EPR policies.

Moreover, integrating the informal sector into the formal waste management framework is essential. Legal recognition and support programs including training and financial assistance, would not only improve waste collection rates but also uplift the socio-economic conditions of informal workers. Public awareness campaigns should be intensified to educate consumers about their role in the EPR system. These campaigns should be tailored to different demographic groups and leverage various media platforms to reach a broader audience. Financial incentives and subsidies are also recommended for independent producers and waste recyclers. Such incentives would encourage compliance and foster innovation in recycling technologies.

Last but not least, establishing robust monitoring and evaluation mechanisms is essential. Leveraging technology, such as Geographic Information Systems (GIS) tracking and data analytics, would enable real-time monitoring of EPR initiatives and allow for data-driven adjustments to policies. By addressing these challenges and opportunities through the recommendedactions, Egypt can significantly enhance the effectiveness of its EPR implementation, This will not only promote a more sustainable waste management system but also contribute to broader environmental and socio-economic benefits, positioning Egypt as a regional leader in EPR and sustainable waste management.

Conclusion

This study highlights the urgent need for a more effective and sustainable waste management system in Egypt, informed by both international best practices and the unique challenges faced within the country. The examination of Extended Producer Responsibility (EPR) practices in developed countries such as Germany, Spain, and Portugal demonstrate that robust legislative frameworks, comprehensive stakeholder engagement, and coordinated implementation strategies play in successful waste management outcomes. These countries have not only integrated EPR principles into their national policies but have also demonstrated the potential for EPR to significantly enhance recycling rates and reduce environmental impact.

In contrast, developing countries like Indonesia and India, while facing distinct challenges, are making noteworthy progress in establishing effective EPR frameworks that suit their local contexts. Indonesia's efforts to incorporate waste banks and market-based collection systems, alongside India's evolving regulatory landscape, highlights the importance of tailoring EPR mechanisms to specific socio-economic conditions and ensuring clear roles of responsibilities among stakeholders.

Egypt's historical attempts to modernize its waste management system have encountered various obstacles, including resistance from traditional garbage collectors and insufficient stakeholder collaboration. Initiatives such as the 2017 "Sell Your Garbage" program, despite their potential, revealed the need for more inclusive planning and collaboration among all involved parties [48]. The establishment of the Waste Management Regulatory Agency (WMRA) in 2015 represents a crucial step towards centralized regulation and monitoring, but further efforts are required to address ongoing challenges and achieve more widespread success [40].

Ultimately, the effective implementation of EPR in Egypt hinges on fostering strong partnerships among government agencies, private sector entities, and local communities. By learning from international best practices and adapting these strategies to the specific needs of the Egyptian context, it is possible to build a sustainable waste management system that not only mitigates environmental impact but also promotes economic growth and social development [7]. Ongoing research, continuous stakeholder engagement, and flexible policy frameworks will be essential components in realizing these objectives and driving progress towards a more sustainable future for Egypt [49].

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