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PLASTIC WASTE MANAGEMENT AND CIRCULAR ECONOMY IN CENTRAL ASIA: BARRIERS, INNOVATIONS AND POLICY PATHWAYS

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Abstract. This article analyses the factors that hinder the development of circular plastic waste management in Central Asian countries and the technological, economic and regulatory pathways for overcoming them. Drawing on reports by the OECD, UNEP and the World Bank, international peer-reviewed literature and the legislation of Uzbekistan and Kazakhstan, the topic is examined along four dimensions: collection and sorting infrastructure, recycling technologies and secondary material markets, regulatory and financial instruments, and regional cooperation and monitoring. The analysis shows that plastic waste cannot be addressed through recycling alone; waste prevention, improved product design, stronger separate collection and viable markets for secondary materials must be pursued together. A five-component conceptual framework adapted to regional conditions is proposed, and research and policy priorities for Uzbekistan are identified.

Keywords: plastic waste, circular economy, recycling, extended producer responsibility, environmental policy, Central Asia, Uzbekistan.

Introduction

Plastics are among the most widely used materials of the modern economy because of their low weight, durability, versatility and low cost. They are used in packaging, construction, agriculture, healthcare, transport and consumer goods. However, a large share of plastic products — especially packaging — has a very short service life, and the resulting waste places a growing burden on municipal waste systems and the environment.

The scale of the problem is well documented. Geyer, Jambeck and Law estimated that by 2015 humanity had produced about 8,300 million tonnes of virgin plastics, of which approximately 6,300 million tonnes had become waste; only around 9% of this waste had been recycled, 12% incinerated and 79% accumulated in landfills or the natural environment [5]. According to the OECD, global plastic production doubled from 234 million tonnes in 2000 to 460 million tonnes in 2019, while plastic waste generation rose from 156 to 353 million tonnes over the same period, and only 9% of plastic waste was ultimately recycled [14]. Jambeck et al. estimated that 4.8–12.7 million tonnes of plastic entered the oceans from land in 2010 alone [8], and later modelling

indicates that current commitments are insufficient to reverse the growth of plastic emissions to aquatic ecosystems [1; 11].

The dominant linear model of "take – make – dispose" is therefore increasingly being challenged by the concept of the circular economy, which aims to keep materials in use for as long as possible through waste prevention, reuse, repair, remanufacturing and recycling [4; 10]. For plastics, the Ellen MacArthur Foundation showed that about 32% of plastic packaging escapes collection systems and only 14% is collected for recycling, indicating that the losses occur at every stage of the material cycle [2]. UNEP emphasises that a system-wide shift combining reduction of unnecessary plastics, reuse, recycling and material diversification could reduce plastic pollution by around 80% by 2040 [17].

Central Asia is a relevant region for examining these issues. Rapid urbanisation, population growth and changing consumption patterns are increasing the volume of municipal and packaging waste, while collection coverage, sorting capacity and data quality vary considerably between countries and between urban and rural areas [18]. The World Bank's regional report identifies the circular economy as an opportunity for resource efficiency in Central Asia, with case studies from Kazakhstan and Uzbekistan [20]. Globally, municipal solid waste generation is projected to grow from 2.01 billion tonnes in 2016 to 3.40 billion tonnes by 2050, with the fastest growth expected in middle-income countries [9]. National governments have also adopted relevant policy documents: in Uzbekistan, the Strategy for Solid Household Waste Management for 2019–2028 sets the target of increasing the share of recycled household waste to 60% by 2028 [21], and the Concept of Environmental Protection until 2030 identifies waste management as a priority area [22]. Kazakhstan has introduced extended producer (importer) obligations within its 2021 Environmental Code [16; 24; 25].

Despite these developments, the scientific literature on circular plastic management in Central Asia remains limited and fragmented. Most available information is contained in international reports rather than in peer-reviewed studies, and national statistics are often not comparable because of differences in definitions and reporting methods.

The aim of this article is to analyse the barriers, technological innovations and policy pathways for circular plastic waste management in Central Asia and to propose a conceptual framework that can guide future research and policy in Uzbekistan.

The objectives of the study are:

1. to identify the main infrastructural, economic and institutional barriers to circular plastic waste management in the region;
2. to assess the potential of waste prevention, reuse, sorting and recycling technologies;
3. to analyse the role of policy instruments, including extended producer responsibility (EPR), in supporting circular material flows;
4. to identify evidence gaps and formulate research priorities for Uzbekistan.

Materials and methods

The study is designed as a narrative (thematic) review. This design was chosen because the topic lies at the intersection of environmental science, economics and public policy, and because the relevant evidence for Central Asia is largely contained in grey literature and legal documents that are not indexed in bibliographic databases.

Sources were identified in Scopus, Web of Science and Google Scholar, in the publication repositories of the OECD, UNEP and the World Bank, and in the official legal databases of Uzbekistan (lex.uz) and Kazakhstan (adilet.zan.kz). Search terms included combinations of "plastic waste", "circular economy", "plastic recycling", "waste collection", "extended producer responsibility", "Central Asia", "Uzbekistan" and "Kazakhstan". English- and Russian-language publications from 2000 to 2025 were considered.

Sources were included if they (a) addressed plastic waste generation, collection, recycling or circular economy policy; (b) were peer-reviewed articles, reports of international organisations or official legal acts; and (c) described their methods or data sources transparently. Promotional materials, sources without identifiable authorship and duplicate publications were excluded. A total of 25 sources were retained for analysis.

The selected literature was analysed using a thematic approach and grouped into four analytical dimensions: (1) infrastructure and technology; (2) economic and market conditions; (3) governance and regulation; (4) regional cooperation and data. Because the review is not systematic, no formal risk-of-bias assessment was performed; this limitation is addressed in the Discussion.

Results

1. Infrastructural and technological barriers

The effectiveness of any recycling system depends on what happens upstream — on the coverage and quality of collection and sorting. When household waste is collected as a mixed stream, recyclable plastics become contaminated with organic residues, moisture and other materials, which sharply reduces their quality and market value [6; 7]. Investment in recycling plants alone is therefore insufficient if the supply of clean, sorted feedstock is unstable.

Separate collection improves material quality, but it requires convenient collection points, regular transport, public participation and sorting capacity. In many cities of the region, the informal sector — individual collectors who recover PET bottles, cardboard and metals — plays an important role in material recovery. International experience shows that informal recyclers can make a significant contribution to recovery rates in developing countries, and that integrating them into formal systems is more effective than displacing them [19].

Technology choice must reflect the composition of the local waste stream. Different polymers (PET, HDPE, LDPE, PP, PS, PVC) have different processing requirements; multilayer packaging and mixed plastics remain difficult to recycle mechanically [15]. Mechanical recycling is the most mature option for clean, single-polymer streams such as PET bottles and HDPE containers, whereas chemical recycling remains costly and energy-intensive and its environmental benefits depend strongly on process conditions [6; 15]. Recycling also involves material losses and

quality degradation over successive cycles, which is why prevention and reuse rank higher in the waste hierarchy [7].

2. Economic barriers and the market for secondary materials

The economic viability of recycling depends on the balance between collection and processing costs and the price of recovered material. When virgin polymers are cheap — which is closely linked to oil and gas prices — recycled plastics struggle to compete [14]. In a region with large distances between settlements and processing facilities, transport costs further reduce profitability.

Additional economic barriers include contamination of collected material, limited processing capacity, lack of quality standards for recycled granulate and limited access to long-term financing. As a result, many recycling enterprises operate with high risk and depend on price fluctuations. The OECD identifies four key levers for improving circularity: stronger markets for secondary plastics, technological innovation, domestic policy measures and international cooperation [14].

Table 1 summarises the main barriers and corresponding response measures identified in the literature.

Table 1. Main barriers to circular plastic waste management and possible responses

Dimension	Main barriers	Possible responses
Infrastructure	Mixed collection, low coverage in rural areas, insufficient sorting capacity	Separate collection, material recovery facilities, integration of informal collectors
Technology	Multilayer and mixed plastics, contamination, quality loss	Design for recycling, polymer-specific processing, quality control
Economy	Cheap virgin plastics, transport costs, unstable demand	Recycled-content requirements, green public procurement, quality standards
Governance	Fragmented responsibilities, weak enforcement, unreliable reporting	EPR schemes, clear institutional roles, transparent reporting
Data	Non-comparable statistics, gap between collected and recycled volumes	Common indicators, material flow accounting, independent verification

Source: compiled by the author based on [2; 6; 14; 15; 17; 19].

3. Regulatory and institutional instruments

Effective plastic waste management requires clearly defined responsibilities for public authorities, producers, collection operators, recyclers and consumers. Where these are fragmented, service delivery becomes inconsistent and information on the final destination of collected waste is lost.

Policy instruments relevant to plastics include product standards, restrictions on selected single-use items, deposit-return systems, separate collection obligations, recycled-content requirements, green public procurement and extended producer responsibility. EPR assigns producers financial and/or organisational responsibility for their products at the post-consumer stage. When well designed, it generates funding for collection and recycling and creates incentives for producers to redesign packaging [12; 13].

However, EPR is not automatically effective. Its performance depends on the scope of covered products, the level of fees, transparent reporting, enforcement and safeguards against overstated recycling figures [12; 13]. Among Central Asian countries, Kazakhstan has an established legal framework for EPR: extended producer (importer) obligations are established in the Environmental Code adopted in 2021, and detailed implementation rules were approved by the Government in the same year [24; 25]. In Uzbekistan, the legal basis for waste management is the Law "On Waste" (2002) [23], supplemented by the 2019–2028 Strategy [21] and the Environmental Protection Concept until 2030 [22]. In January 2025, a draft proposal to ban plastic bags from 2027 was announced for public discussion [3], which indicates growing policy attention to upstream measures.

The experience of these two countries shows that policy transfer must be approached with caution: an instrument that works in the European Union may require substantial adaptation where collection infrastructure, administrative capacity and market conditions differ.

4. Regional cooperation and data quality

The five Central Asian countries differ in population distribution, economic structure, infrastructure and data availability, and the region should not be treated as a uniform waste management system [18; 20]. At the same time, they share common challenges: long transport distances, dependence on imported packaging, limited recycling capacity and weak waste statistics. This creates scope for cooperation in harmonising indicators, exchanging technical experience, training municipal specialists and developing joint research projects.

Reliable data are essential for evaluating circular economy interventions. The amount of waste collected is not equal to the amount recycled, and the amount entering a recycling facility is not equal to the quantity of usable secondary material produced. A robust monitoring system should distinguish between the stages shown in Table 2.

Table 2. Recommended indicators for monitoring plastic material flows

No.	Indicator	Purpose

No.	Indicator	Purpose
1	Plastic waste generated (t/year, kg per capita)	Baseline for all other indicators
2	Plastic waste collected by formal systems	Coverage of collection services
3	Plastic waste separately collected or sorted for recycling	Effectiveness of separate collection
4	Material entering recycling facilities	Actual feedstock supply
5	Secondary material meeting quality requirements	Real recycling output
6	Residues and process losses	Efficiency of recycling
7	Plastic leakage to the environment (estimate)	Environmental outcome

Source: developed by the author based on [2; 14; 17].

Discussion

The results confirm that plastic waste management should be treated as an interconnected system rather than a set of separate technical activities. Collection, sorting, recycling, market demand, product design and regulation influence one another: investment in a recycling plant brings little benefit if the feedstock is inconsistent, and separate collection fails if the collected materials are later mixed or if there is no market for them. This conclusion is consistent with the analyses of the OECD [14] and UNEP [17], as well as with global modelling studies showing that recycling alone cannot keep pace with the growth of plastic waste [1; 11].

On this basis, a five-component framework for circular plastic management in Central Asia is proposed (Table 3).

Table 3. Conceptual framework for circular plastic management in Central Asia

Component	Content	Main actors
1. Prevention and design	Reducing unnecessary plastics; packaging designed for reuse and recycling	Producers, retailers, regulators
2. Collection and	Accessible separate collection; reducing contamination; integrating	Municipalities, collection

Component	Content	Main actors
sorting	informal collectors	operators
3. Recycling and markets	Polymer-appropriate technologies; quality standards; demand for recycled content	Recyclers, industry, public procurement
4. Governance and finance	Clear responsibilities; EPR; targeted financial incentives	Government, producer responsibility organisations
5. Monitoring and learning	Comparable indicators; independent verification; regional exchange	Statistics agencies, researchers, international partners

Source: developed by the author.

The framework is conceptual and has not yet been tested empirically. Its value lies in showing which elements must be developed simultaneously and in providing a structure for evaluating policies.

Implications for Uzbekistan. The national target of recycling 60% of household waste by 2028 [21] makes reliable measurement of plastic flows a practical necessity. Three research priorities follow from the analysis. First, studies of waste composition are needed to determine the quantities and types of plastics generated, collected, sorted and recycled in cities and rural areas. Second, technologies should be assessed using transparent criteria — operating costs, material quality, energy consumption, environmental impacts and market availability. Third, policy instruments (the planned restriction of plastic bags, possible EPR mechanisms, public procurement requirements) should be evaluated against measurable outcomes, such as verified recycling output and reduction of contamination, rather than the fact of their adoption.

Limitations. This review is narrative rather than systematic, and the selection of sources may not be exhaustive. Country-specific data for Central Asia are limited and not always comparable, and the proposed framework has not been validated through field research or modelling. Quantitative claims about national waste generation and recycling should be verified against primary sources and their reporting periods.

Conclusion

1. Plastic waste management in Central Asia requires an integrated approach that combines waste prevention, improved collection and sorting, appropriate recycling technologies, viable secondary material markets and effective governance. Recycling is necessary but cannot resolve the problem on its own.
2. The main barriers in the region are mixed collection and contamination, limited processing capacity, the low competitiveness of recycled materials compared with virgin polymers, fragmented institutional responsibilities and non-comparable statistics.

3. Extended producer responsibility is a promising instrument, as the introduction of a legal framework for it in Kazakhstan illustrates, but its effectiveness depends on transparent reporting, enforcement and adaptation to local conditions.
4. For Uzbekistan, priority should be given to waste composition studies, a unified system of plastic flow indicators, transparent assessment of technologies and outcome-based evaluation of policy instruments in line with the targets of the 2019–2028 Strategy.
5. The proposed five-component framework can serve as a basis for future empirical research and for designing coordinated regional policies.

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