Brief Report

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Impact of the Implementation of the Deposit Refund System on Coastal Littering in Latvia

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Abstract: This paper provides a comprehensive evaluation of the environmental impact of implementing the beverage container DRS on marine and coastal litter along the Latvian coastline. It incorporates data and insights from the assessment of deposit fractions litter in coastal areas during the post-season autumn period in three monitoring sessions from 2021 (before the introduction of the DRS in Latvia) to 2023 (post-introduction). In 2022, a 43% overall decrease in selected public coastal areas was observed, with significant reductions at 11 out of 17 sites. This positive trend continued in 2023, showcasing a further 22% decrease compared to 2022 and a substantial 56% decrease compared to 2021. The study delves into the specific impact on different material types of beverage containers, reporting significant decreases in plastic and aluminum litter fractions. While glass beverage container litter showed a smaller decrease, overall positive trends continued in 2023. However, the situation with aluminum cans remained challenging, especially in border areas with Lithuania and Estonia. The study emphasizes that beverage containers with identifiable deposit system labels constitute a minority of the total litter pressure, underscoring the need for ongoing efforts to address containers without deposit labels, particularly in specific border areas. The findings provide valuable insights into the effectiveness of the deposit system in mitigating coastal litter, contributing to sustainable waste management practices in Latvia.

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1. Introduction

A Deposit Return System (DRS) is a beverage container collection method used by many countries with the objective to improve collection rates and circularity of beverage packaging (mostly plastic, metal, and glass) and reduce littering. DRS has been used for decades by manufacturers of beverages and beer in order to maximize the collection of reusable glass bottles. This collection method based on deposit was adopted for single use containers. For the first time in Canada, in British Columbia (1970). The first European country which imposed deposit on non-refillable beverage packaging was Sweden and the nationwide deposit system started operating there in 1984 [1]. Recent Global Deposit Book [2] suggests that in 2022 the system was introduced in 50 jurisdictions, including several states of the USA, Australia, and European countries. As of 1st of February 2024, 16 European states (EU and EEA members) have implemented a deposit scheme as a collection method for recyclable containers (Sweden, Norway, Denmark, Iceland, Finland, Germany, Netherlands, Croatia, Estonia, Latvia, Lithuania, Slovakia, Romania, Malta, Hungary and Ireland).

Many studies have demonstrated the positive economic outcomes of implementing DRS and identified several "best practices" to enhance its effectiveness. For instance, an evaluation of the Latvian DRS [3] indicates that implementing the system demands significant financial and organizational resources. This burden could be mitigated by introducing DRS after establishing

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separate waste collection systems first. Moreover, other studies [4,5] have emphasized the importance of ensuring that the economic costs associated with DRS do not outweigh its environmental benefits.

In addition to boosting beverage container recycling rates, a significant advantage of DRS—unattainable without its implementation—is a reduction in litter [3,6,7]. Littering has a significant negative impact on the environment and wildlife [8,9] as well as causes negative costs to people and the economy [10,11]. Various studies have conducted litter rate comparisons between jurisdictions with and without DRS [12,13]. However, there is a lack of comprehensive longitudinal studies examining the changes in littering following the introduction of DRS.

This paper aims to systematically compare changes in littering in Latvia before, shortly after the implementation, and 1.5 years after the introduction of the DRS in February 2022. By focusing on Latvia's experience, this study seeks to contribute to the existing body of knowledge on the impact of DRS on coastal littering and provide valuable insights for policymakers and stakeholders involved in waste management and environmental protection.

2. Materials and Methods

After nearly two decades of deliberation, Latvia's DRS commenced operations in February 2022. The eligible container types include carbonated and non-carbonated non-alcoholic beverages (such as drinking water, mineral water, lemonade, energy drinks, iced teas, juices, nectars), beer, and other fermented products with an alcohol content of up to 6% (e.g., cider, alcohol cocktails with an alcohol content ranging from 0.5% to 6%). The system excludes wine (including sparkling wine and fruit wine), hard liquor, milk, dairy products, and aseptic containers. The accepted material types comprise plastic (mainly PET), metal (aluminium, steel), and glass.

Latvia has adopted the return-to-retail method within the DRS framework. Under this approach, retailers with a floor space of ≥60 m^2 in rural areas and ≥300 m^2 in larger cities are mandated to establish a collection point. These points must accept all types of deposit packaging either at the point of sale, on the retailer's premises, or in close proximity to the sales point, with a distance not exceeding 150 m from the point of sale. At the launch of the system, there are approximately 1,350 return locations in Latvia.

Coastal and marine littering is an ongoing environmental concern [14], with significant impacts on ecosystems, wildlife, and human health. The implementation of DRS represents a proactive measure aimed at mitigating this issue. By incentivizing the return of beverage containers for recycling through a refundable deposit, DRS encourages proper disposal and recycling practices among consumers. Consequently, the introduction of DRS seeks to reduce littering, particularly of items like glass bottles, plastic bottles, and aluminum beverage cans, thereby contributing to the preservation of coastal and marine environments.

In this study, we conducted an assessment of the snapshot situation concerning the presence of coastal and marine litter from deposit fractions in Latvia before and after the introduction of the DRS. We used point-based monitoring in two distinct types of coastal sites during the post-season autumn period across three monitoring sessions spanning from 2021 to 2023 (weeks 3-4 in October and week 1 in November). These site types include dune areas, referred to as type 1, and access points to the beach used as parking places and pathways, referred to as type 2. This sampling strategy was chosen to enhance the potential detection of littered objects.

These areas are renowned for their tendency to accumulate litter and serve as valuable sources of information about littering habits. To ensure data comparability and eliminate any unknown periods of accumulation, we selectively chose only publicly managed sites accessible to the public all year round. Latvia has a relatively long coastline (504 km) and in total we selected 17 sites for monitoring, strategically located along the entire Latvian coastline (see Figure 1). Specifics of the sites and sampling transects are available in the Supporting Information.

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Figure 1. Coastal litter monitoring sites in Latvia.

The specific location and length of the transects varied depending on the site and the available access routes, resulting in transect lengths ranging from 266 meters to 1.11 kilometres. However, for the purposes of this study, the focus lies not on the length of the transects but on the comparison between the years. Each transect was divided into several quadrats, each measuring 2 meters by 2 meters, systematically positioned along the transect line for sampling purposes. The method involved manually collecting litter within these quadrats by trained volunteers. The precise locations were documented using GPS. This approach allowed for accurate mapping and identification of the study sites, ensuring that data collection and analysis were conducted with precision. To ensure consistency in the sampling methodology, the same quadrats were utilized for sampling across three consecutive years.

In this study, we categorized beach litter into free groups according to the DRS classification: glass bottles, plastic bottles, aluminum beverage cans. During the survey, all items visible to the naked eye were identified and recorded on provided survey forms. By meticulously cataloguing each item, researchers could gather detailed data regarding the types, quantities, and distributions of litter present in the study areas. For each deposit fraction examined, we individually assessed their sizes, providing additional data for potential further analysis of littering habits. We excluded other forms of DRS related litter such as cups. Starting from the year 2022, we enhanced the monitoring protocol to include the identification of the presence of the deposit system label for each litter item.

The collected data reflects the post-summer-season situation and the rate of litter accumulation in conditions where daily site waste maintenance activities are absent. During the data collection process, we also identified the type of waste management infrastructure in place, recognizing its potential impact on littering habits. This involved documenting the presence of waste bins and containers on-site, specifying the types of containers, and noting whether there were waste containers for recyclable waste categories. It should be noted that, according to available information, off-season maintenance varied from 2 days to 1 week in most sites, with only 2 to 3 exceptions where it was not possible to reliably ascertain waste management routines.

3. Results

Table 1 demonstrates summarized data for all 17 monitoring sites between 2021 and 2023. The results show considerable improvements as the deposit system-linked litter fractions numbers have decreased considerably since the introduction of the deposit return system in February of 2022.

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Table 1. summary of the findings with regards to the impact of deposit system implementation litter fractions in selected coastal hotspots (Oct-Nov 2021 vs Oct-Nov 2022 and Oct-Nov 2023).

No	Site	Type	WM	2021	2022	2023	Change 22vs21	Change 23vs21	Change 22/23vs21
1	Užava	2	no	25	4	11	-84%	-56%	-70%
2	Pavilosta	2	mix, recyclables	5	3	1	-40%	-80%	-60%
3	Pape	2	closed, recyclables	9	5	3	-44%	-67%	-56%
4	Karosta	1&2	closed, recyclables	12	6	6	-50%	-50%	-50%
5	Zvejniekciems	1&2	open	22	23	16	5%	-27%	-11%
6	Salacgriva	1&2	no	44	17	19	-61%	-57%	-59%
7	Lilaste	2	closed, recyclables	6	2	2	-67%	-67%	-67%
8	Daugavgriva	2	open	71	36	12	-49%	-83%	-66%
9	Vakarbulli	2	closed, recyclables	5	2	2	-60%	-60%	-60%
10	Vitrupe1	1&2	closed	19	22	19	16%	0%	8%
11	Vitrupe2	1&2	closed	7	10	11	43%	57%	50%
12	Vitrupe3	1&2	closed, recyclables	6	12	9	100%	50%	75%
13	Kolka	2	no	14	2	3	-86%	-79%	-82%
14	Roja	2	closed	0	0	0	0%	0%	0%
15	Mersrags	2	closed, recyclables	0	0	0	0%	0%	0%
16	Abragciems	2	no	10	1	0	-90%	-100%	-95%
17	Lielupe	2	closed, recyclables	2	1	0	-50%	-100%	-75%
			Total	257	146	114	-43%	-56%	-49%

As of 2022, there was a significant overall reduction of 43% in selected public coastal areas when compared to 2021 (average amounts of selected litter types across 17 chosen coastal locations). Among the surveyed sites, 11 experienced substantial decreases both in terms of quantity and percentage, while only 5 sites showed no change or a deterioration in the situation.

The positive trends persisted in 2023, with a further 22% decrease when comparing data from 2022 and 2023, and an overall reduction of 56% compared to 2021, the year preceding the introduction of the deposit return scheme. This results in an overall decrease of 49% in deposit system-related litter across the selected 17 coastal sites during the years 2022 and 2023 since the implementation of the deposit return system.

However, it is crucial to consider the limitations of the survey methodology and exercise caution when interpreting the data. The survey comprises only three monitoring sessions, and improvements or deteriorations may be linked to broader changes in coastal management within certain municipalities.

The subsequent analysis of survey data focuses on developments related to specific material beverage containers, with Table 2 providing a summary of the observed situation and trends for different material beverage containers.

Table 2. hotspot survey summary data comparison 2021 vs 2022/2023 – total by type/average by the material of the beverage containers.

	Plastic bottles			Aluminium cans			Glass bottles		
	0,5	>0,5	Other (0,2/0,33)	0,5	>/= Pint	Other (<0,5)	<0,5	0,5&Pint	>=0,7
Total by type 2021	29	62	8	47	25	16	19	41	10
Average by material 2021	5,8			5,2			4,1		
Total by type 2022	16	27	2	19	11	7	15	33	16
Average by material 2022	2,6			2,2			3,8		
Total by type 2023	1	13	17	13	13	21	9	17	10
Average by material 2023	1,8			2,8			2,1		
Change 22vs21	-54%			-58%			-8%		
Change 23vs21	-69%			-47%			-48%		
Change 22/23vs21	-61%			-52%			-28%		

In 2022, data revealed a substantial reduction in selected litter fractions for two materials, with a 54% decrease for plastic beverage containers and a 58% decrease for aluminum cans. Meanwhile, the decrease in glass beverage containers, though present, was smaller at 8%. Various factors, such as the inclusion of container types in the deposit system, overall circulation, and public perceptions and habits, may contribute to these differences.

In 2023, positive trends persisted for plastic and glass beverage containers, showing respective decreases of 69% and 48% compared to the situation in 2021. However, the situation regarding aluminum cans did not improve. It is noteworthy that in 2023, larger quantities of identified beverage

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cans without Latvian deposit system labels were observed in sites near the border areas with Lithuania and Estonia (Pape, Vitrupe 1, Vitrupe 2, Vitrupe 3).

Overall, when comparing data from before the deposit system launch (2021) to average data from 2022 and 2023, the decreases were as follows: 61% for plastic bottles, 52% for aluminum cans, and 28% for glass bottles.

From the 2022 surveys conducted after the deposit system was fully functional, the monitoring protocols included an additional parameter – the identification of whether beverage containers had deposit labels. While providing an additional perspective on the survey data, this parameter has limitations, especially concerning glass bottles, where labels are more prone to weather-related wear and tear.

As indicated in Tables 3 and 4, beverage containers with identifiable deposit system labels constitute a minority of the total litter pressure for their respective waste fractions – 18% in 2022 and 25% in 2023. The increase in the share of labelled items in 2023 aligns with the significant circulation growth of these fractions. However, it is essential to highlight that a considerable share of beverage containers without deposit system labels persists, particularly noteworthy in 2023, where a concentration of such containers was identified on monitoring sites near the Latvian-Estonian and Latvian-Lithuanian borders. Approximately one-third of containers still could not have the presence of the label identified.

Table 3. coastal litter on survey sites by label type in 2022 and 2023 monitoring sessions (deposit label/no deposit label/unclear alignment).

Type	Plastic bottles			Alluminium cans			Glass bottles		
	Deposit	No deposit	Unclr	Deposit	No deposit	Unclr	Deposit	No deposit	Unclr
2022	3	18	24	12	20	5	11	34	19
	7%	40%	53%	32%	54%	14%	17%	53%	30%
	45			37			64		
2023	Deposit	No deposit	Unclr	Deposit	No deposit	Unclr	Deposit	No deposit	Unclr
	5	11	15	20	19	8	3	20	13
	16%	35%	48%	43%	40%	17%	8%	56%	36%
	31			47			36		

Table 4. coastal litter on survey sites by label type in 2022 and 2023 monitoring sessions – summary.

	2022	2023
Deposit total	18%	25%
No label total	49%	44%
Unclear total	33%	32%

4. Discussion and Conclusions

The DRS is not only an economically [15–17] and organizationally [1] feasible tool to improve recycling but also offers the most environmentally sustainable solution for managing beverage packaging at the end of its use [1,18]. This paper provides additional arguments for the environmental sustainability of the DRS systems by evaluating the impact of implementing the beverage container DRS on marine and coastal litter along the Latvian coastline. It incorporates data and insights from the assessment of deposit fractions litter in coastal areas during the post-season autumn period in three monitoring sessions from 2021 (before the introduction of the DRS in Latvia) to 2023 (post-introduction).

Comparing the results from 2021 to 2023 in selected coastal sites, the study indicates a discernible positive impact following the introduction of the beverage container DRS in Latvia. In 2022, there was a 43% overall decrease in DRS-related beverage packaging litter in selected public coastal areas, with significant reductions observed at 11 out of 17 sites. This positive trend continued in 2023, with a further 22% decrease compared to 2022 and a substantial 56% decrease compared to 2021 when the deposit return system was not yet implemented. The overall reduction in deposit system-related litter items across the 17 coastal sites in 2022 and 2023 was 49%.

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These results are in line with studies from other countries. For example, before the mandatory DRS was implemented in Germany, approximately one-fifth of the total litter volume was attributed to single-use beverage containers. However, following the introduction of the system, the littering of single-use beverage containers subject to deposits in the country has been reported to be negligible [19]. More recent studies have compared littering between areas where the DRS has been introduced and those where it has not. According to a 2018-2019 report by Keep South Australia Beautiful [12], beverage container litter accounted for only 2.9% of litter items in South Australia, where DRS has been in place since 1977, in contrast to 14.2% in Western Australia, which lacked a DRS at that time. Another study [13] observed considerably lower overall litter in US states with functional DRS. On a per capita basis, states with DRS exhibited 50% less deposit material litter and 30% less non-deposit material litter compared to states without a DRS.

This reduction in the littering of plastic, aluminum, and glass materials is of paramount importance for environmental conservation. The global problem of littering and related pollution is escalating rapidly, driven by the proliferation of a throw-away culture marked by excessive consumption and the overproduction of disposable items [20]. Our study results from 2022 revealed a notable decrease in litter fractions for all these materials, with plastic beverage containers showing a reduction of 54%, aluminum cans decreasing by 58%, and glass beverage containers experiencing a more modest decrease of 8%. In 2023, positive trends continued for plastic and glass beverage containers, with respective decreases of 69% and 48% compared to 2021. When comparing data from before the deposit system's launch (2021) with average data from 2022 and 2023, the decrease was as follows: 61% for plastic bottles, 52% for aluminum cans, and 28% for glass bottles.

The decrease in the DRS-related beverage packaging litter demonstrates that DRS effectively motivates people to return their beverage containers for recycling, reducing the likelihood of these containers being littered. The introduction and promotion of the DRS likely raised public awareness about the importance of recycling and proper disposal of beverage containers. This increased awareness can lead to more responsible behaviour among consumers. Also, regular monitoring and reporting of litter data can help identify problem areas and inform targeted interventions, leading to more effective litter reduction strategies.

However, we can see that even when DRS exist in both Estonia and Lithuania a notable trend in 2023 identified a concentration of DRS-related beverage packaging litter near the coastal sites on the Latvian-Estonian and Latvian-Lithuanian borders. Thus, cross-border tourism may be influencing coastal littering and decrease the effectiveness of the DRS in littering reduction. Lack of awareness about the DRS labelling or infrastructure could lead to confusion and increased littering at the borders. Additionally, a potential increase in cross-border tourism in 2023 after the COVID-19 restrictions have been lifted could have contributed to the concentration of DRS-related litter near the borders.

These results underscore the effectiveness of targeted efforts to mitigate littering, highlighting the significance of addressing litter across different material types to achieve comprehensive environmental improvements. The system encourages recycling and effectively reduces the amount of beverage container litter that ends up in coastal and marine environments, especially for plastic and aluminum containers. The more modest reduction in glass bottle litter might be attributed to the existing practices of glass bottle recycling in the absence of the DRS.

The consistent decrease over two consecutive years suggests that the positive effects of the DRS for commonly discarded items such as beverage containers are sustainable and likely to continue in the future. DRS has been proven to be one of the most effective ways of dealing with littering as imposing a direct tax on litter presents significant challenges, particularly in terms of monitoring and enforcement. This approach encourages responsible disposal by providing a financial incentive for returning items for reuse or recycling, thereby mitigating litter pollution and promoting environmental sustainability. This is a significant argument to be considered by all these countries (e.g. Slovakia, Spain, Bulgaria) considering the introduction of the DRS.

However, several limitations in the study and methodology should be considered in interpreting the data:

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- The survey of coastal littering hot spots included only three monitoring sessions, making findings situational in some places.
- Improvements in coastal sites may be interlinked with broader coastal management enhancements in some municipalities.
- Some "unidentified" deposit label presence in 2022 coastal spots may be due to worn-off tags, especially for glass bottles.

Supplementary Materials: The following supporting information can be downloaded at the website of this paper posted on Preprints.org. Hotspot Survey Sites Data Profiles and Sampling Transects.

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