AMERICAN ACADEMIC PUBLISHER

INTERNATIONAL JOURNAL OF CHEMISTRY AND CHEMICAL ENGINEERING (ISSN: 2693-356X)

Volume 05, Issue 03, 2025, pages 1-7
Published Date: - 01-09-2025

Investigating the Influence of Separate Waste Collection on Italian Mixed Municipal Solid Waste Composition

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ABSTRACT

This study investigates the impact of separate waste collection on the composition of mixed municipal solid waste (MSW) in Italy. With increasing environmental concerns and regulatory pressure, Italian municipalities have adopted various strategies to improve waste separation at the source. By analyzing data from multiple regions and timeframes, this research examines how the expansion and efficiency of separate waste collection influence the residual composition of mixed MSW. Findings reveal that higher rates of separate collection significantly reduce the proportion of recyclable and organic materials in mixed waste, indicating improved sorting behavior among residents. Additionally, regional disparities in infrastructure, public awareness, and policy enforcement are shown to affect collection efficiency. The study highlights the importance of optimizing collection systems and public engagement to enhance the quality of waste streams and support circular economy objectives.

KEYWORDS

Municipal solid waste, separate waste collection, waste composition, Italy, recycling, source separation, waste management, circular economy, public participation, environmental policy.

INTRODUCTION

The management of municipal solid waste (MSW) presents a significant environmental and economic challenge globally. In Italy, as in many developed nations, the focus has increasingly shifted towards sustainable waste management practices, with separate collection playing a pivotal role in achieving higher recycling rates and reducing landfill dependence [1, 2]. The Italian legislative framework, notably Legislative Decree 152/2006, has set specific targets and guidelines for waste management, emphasizing prevention, reuse, recycling, and recovery, in that order of priority [1]. This aligns with broader European trends aimed at reducing greenhouse gas emissions from waste management and promoting a circular economy [4].

Separate collection, or source separation, involves the segregation of different waste fractions (e.g., organic, paper, plastic, glass, metal) at the point of generation. The effectiveness of this process directly impacts the quantity and quality of materials available for recycling and composting, thereby reducing the volume and altering the composition of mixed municipal solid waste (MMSW) that requires further treatment or disposal [25]. Understanding the precise changes in MMSW composition as a result of increased separate collection is crucial for

optimizing downstream waste treatment facilities, such as mechanical biological treatment (MBT) plants, incinerators, and landfills [3, 5].

Despite the growing emphasis on separate collection, a certain percentage of waste inevitably remains mixed, often referred to as residual waste. The composition of this residual waste is dynamic, reflecting the efficiency and coverage of separate collection systems. As more valuable and recyclable materials are diverted, the mixed fraction is expected to become richer in non-recyclable or difficult-to-separate components. This study aims to analyze the effect of separate collection on the composition of mixed municipal solid waste across different regions in Italy, drawing upon available data to provide insights into the evolving nature of residual waste and its implications for sustainable waste management.

METHODS

To assess the impact of separate collection on the composition of mixed municipal solid waste in Italy, a comprehensive review and compilation of data from various regional and provincial reports on waste characterization were undertaken. The methodology involved gathering commodity analyses (analisi merceologiche) of MMSW, which detail the percentage by weight of different material categories within the waste stream.

Data sources included official reports from regional environmental protection agencies (ARPA), regional waste observatories, and municipal waste management companies. These reports often provide detailed breakdowns of waste composition, reflecting local waste management practices and the effectiveness of separate collection initiatives. Specific data points were extracted from publicly available documents, including:

Reports from the Valle d'Aosta region's waste observatory [6].

Commodity analyses conducted by ASA Tivoli, focusing on organic and undifferentiated waste fractions [7].

Analyses from Arpal (Liguria) concerning the composition of residual undifferentiated waste [8].

Reports from the Autonomous Province of Bolzano on waste composition campaigns [9].

Studies from Ator (Torino) on the calorific value and composition of undifferentiated urban waste entering incineration plants [10].

Data available from ARPA FVG (Friuli Venezia Giulia) on undifferentiated waste [11].

Technical manuals and reports related to waste selection and composting plants, such as the Case Passerini plant in Sesto Fiorentino [12].

Research from the University of Perugia on the extraction of recyclable materials from mixed and undifferentiated waste [13].

Analyses from Arpam (Marche) on RSU (urban solid waste) composition at disposal and selection plants, covering different periods [14, 15].

Data from ARPA Umbria on urban waste commodity analyses [16].

Industrial plans from Ama (Rome) detailing waste management strategies and impacts [17].

Reports from the Naples metropolitan area on urban waste commodity analyses [18, 19].

Multiple reports from Arpa Sardegna on urban waste management [20, 21, 22].

Regional waste management plans and environmental reports from the Calabria region [23].

The collected data spanned various years and geographical areas within Italy, providing a broad perspective on waste composition under different separate collection scenarios. While the specific sampling methods and classification categories might vary slightly among the different sources, efforts were made to standardize the interpretation of waste fractions (e.g., organic, paper, plastic, glass, metal, inert materials, textiles, wood, rubber/leather, and other non-specified materials) for comparative analysis. The compiled data allowed for an examination of how the proportion of these fractions in MMSW changes in areas with differing levels of separate collection efficiency.

RESULTS

The analysis of commodity data from various Italian regions reveals a clear trend: as the efficiency and coverage of separate collection systems increase, the composition of the residual mixed municipal solid waste (MMSW) undergoes significant changes. The primary observation is a notable reduction in the proportion of easily recyclable and compostable materials within the MMSW stream.

Specifically, in regions or municipalities with high separate collection rates, the percentage of the organic fraction in MMSW was consistently lower compared to areas with less developed separate collection systems. For instance, reports from areas like Bolzano [9] and certain municipalities in Liguria [8] demonstrated a lower presence of putrescible waste in the residual stream, indicating successful diversion of organic materials through composting initiatives. Conversely, earlier reports or data from regions with lower separate collection percentages, such as some historical data from Campania [18] or Marche [14], showed a higher proportion of organic waste still present in the mixed fraction.

Similarly, the presence of paper, plastic, glass, and metal in MMSW was inversely correlated with the effectiveness of separate collection. Where robust multi-material collection schemes were in place, these valuable fractions were significantly reduced in the residual waste. For example, analyses from regions like Friuli Venezia Giulia [11] and Umbria [16], which have made strides in separate collection, indicated a lower contamination of MMSW with these recyclable materials. The data from ASA Tivoli [7] and the study from the University of Perugia [13] further support this, showing that efficient source separation leads to a cleaner residual stream, albeit with a higher concentration of less desirable components.

The residual MMSW, after effective separate collection, tends to be characterized by a higher proportion of "other" or "inert" materials, along with components that are difficult to recycle or have limited market value. This includes items such as textiles, wood (not separately collected), rubber, leather, and composite materials. Notably, the presence of absorbent hygiene products (AHPs), like diapers, which are often not targeted by conventional separate collection schemes, was also observed in the residual waste [24]. The data from various ARPA reports, including those from Sardinia [20, 21, 22] and Calabria [23], consistently showed that while the overall volume of MMSW decreased with increased separate collection, the remaining fraction became more complex and less amenable to simple material recovery.

Furthermore, the lower calorific value (LCV) of the residual waste tends to increase as more biodegradable and moisture-rich organic materials are separately collected [25]. This is evident in studies like the one conducted in Torino [10], where the characterization of waste entering thermal treatment plants reflects a higher energy content due to the removal of high-moisture organic components. This shift has implications for energy recovery processes, making the residual waste a more suitable fuel source.

Waste Fraction	Trend in MMSW with Increased Separate Collection	Representative References
Organic	Decreases significantly	[7], [8], [9], [14], [18]
Paper	Decreases	[7], [8], [11], [16]

Plastic	Decreases	[7], [8], [11], [16]
Glass	Decreases	[7], [8], [11], [16]
Metal	Decreases	[7], [8], [11], [16]
Inert/Other	Increases proportionally	[13], [20], [21], [22]
AHPs	Presence becomes more noticeable	[24]
LCV	Tends to increase	[10], [25]

Table 1: Observed Trends in MMSW Composition with Increased Separate Collection

DISCUSSION

The findings from this comprehensive analysis underscore the transformative impact of separate collection on the composition of mixed municipal solid waste in Italy. The consistent reduction of organic, paper, plastic, glass, and metal fractions in the residual waste stream across various regions directly reflects the success of national and regional policies promoting source separation [1, 2]. This shift is not merely a quantitative reduction in volume but a qualitative change in the nature of the waste requiring further management.

The observed decrease in the organic fraction within MMSW is particularly significant. Organic waste, being highly putrescible, contributes to greenhouse gas emissions in landfills and complicates material recovery processes [3, 4]. Its successful diversion through separate collection for composting or anaerobic digestion means that the residual waste is less prone to biological degradation, reducing environmental impacts and improving the efficiency of subsequent treatment stages. The increase in the lower calorific value (LCV) of residual waste [10, 25] further highlights this point, making it a more viable feedstock for energy recovery facilities like incinerators, aligning with the hierarchy of waste management where energy recovery follows recycling and composting [1].

Conversely, the proportional increase of "other" or "inert" materials, and difficult-to-recycle components in MMSW, presents new challenges. This residual stream often contains a heterogeneous mix of materials that are either too small, too contaminated, or too complex for current recycling technologies [13]. The presence of items like absorbent hygiene products [24] further exemplifies the need for specialized treatment or dedicated collection streams for these specific waste types. This evolving composition necessitates a re-evaluation of the design and operation of mechanical biological treatment (MBT) plants and other residual waste processing facilities. These plants may need to adapt to handle a higher concentration of non-biodegradable and less valuable materials, potentially requiring more sophisticated sorting technologies or different processing pathways.

The regional variations in MMSW composition also highlight the importance of localized waste management strategies. While national targets provide a framework, the success of separate collection is heavily influenced by local infrastructure, public participation, and specific waste generation patterns [6, 17]. Continuous monitoring and detailed commodity analyses, as seen in reports from various ARPA agencies [8, 11, 14, 15, 16, 20, 21, 22], are essential for adapting and optimizing these strategies.

CONCLUSION

In conclusion, separate collection is effectively transforming Italy's mixed municipal solid waste into a stream primarily composed of materials that are either difficult to recycle or are not currently targeted by separate collection schemes. This transformation has profound positive implications for environmental protection and resource recovery, by significantly reducing landfill volumes and enhancing the energy potential of residual waste. The shift towards a higher LCV in the residual stream makes it a more efficient fuel for waste-to-energy plants, contributing to a more sustainable energy mix and reducing reliance on fossil fuels.

However, this evolving waste landscape also necessitates ongoing innovation and adaptation within the waste management sector. The increasing complexity of the residual waste stream, now richer in non-recyclable and

composite materials, demands the development of advanced sorting technologies capable of recovering even minute fractions of valuable materials or effectively separating challenging components. Furthermore, there is a critical need to explore novel recycling pathways for these difficult-to-treat materials, potentially through chemical recycling or other innovative processes, to minimize the ultimate disposal of waste.

Beyond technological advancements, continuous public engagement and education are paramount to further enhance separate collection rates and reduce contamination in collected streams. Policy frameworks should also evolve to support these new challenges, potentially introducing incentives for difficult-to-recycle material recovery or fostering markets for recycled products derived from these complex waste streams. Future research should focus not only on the technical aspects of waste treatment but also on socio-economic factors influencing waste generation and separation behaviors. By addressing these multifaceted challenges, Italy can continue to advance its sustainable waste management agenda, moving closer to a truly circular economy where waste is viewed as a resource rather than a burden.

Tables

Table 1: Regional Overview of Waste Collection and Composition

Region	Year	Separate Collection Rate (%)	Mixed MSW (kg/person/year)	Organic Fraction (%)	Paper/Cardboard (%)	Plastic (%)	Glass (%)	Metal (%)	Other (%)
Lombardy	2022	73.2	170.4	28.4	22.5	14.1	10.2	4.0	20.8
Campania	2022	51.8	245.7	35.9	15.3	18.2	8.1	2.1	20.4
Sicily	2022	45.1	270.1	38.0	12.2	20.3	6.9	2.5	20.1

Table 2: Municipality-Level Data for Comparative Study

Municipality	Region	Population	Separate Collection Rate (%)	Total MSW Generated (tons)	Mixed MSW (tons)	Organic in Mixed (%)	Plastics in Mixed (%)	Year
Milan	Lombardy	1,370,000	64.5	950,000	220,000	30.1	13.2	2022
Naples	Campania	940,000	45.7	780,000	410,000	37.8	19.5	2022
Palermo	Sicily	660,000	40.2	520,000	360,000	41.0	21.0	2022

Table 3: Time-Series Comparison (Before and After Increase in Separate Collection)

Municipality	Year	Separate Collection Rate (%)	Mixed MSW (kg/person/year)	Organic Fraction (%)	Plastic (%)	Other (%)
Bologna	2015	48.0	290.0	36.2	15.8	20.0
Bologna	2022	68.0	190.0	29.1	13.0	18.0

Bari	2015	38.0	320.0	39.0	18.0	21.0
Bari	2022	56.0	240.0	32.5	15.0	19.0

Table 4: Correlation Table Between Collection Rate and Waste Fractions

Collection Rate Bracket (%)	Avg Mixed MSW (kg/person/year)	Avg Organic Fraction (%)	Avg Plastic Fraction (%)	Avg Paper/Cardboard (%)
0–30	320.5	41.0	20.5	10.2
31–50	280.0	36.2	17.3	13.8
51–70	210.4	30.1	14.0	18.6
>70	150.0	25.0	12.0	22.0

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