FULL PAPER SUBMISSION for the HERAKLION 2019

7th International Conference on Sustainable Solid Waste Management

Scenario of the plastic waste recycling in Emilia Romagna Region (Italy) as effort for the recent European Strategy for plastics in a circular economy

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ABSTRACT

The evidence of the impact of the mismanagement of plastic goods in the environment has captured the attention of scientists, policy makers and manufacturers. Urgent measures, regarding to a combination of preventing plastic use and massively improving waste management have been acclaimed by different stakeholders with the common goal to make a more resilient and competitive plastic industry. European Commission has pledged itself publishing the first EU-wide policy framework on plastics. The new recycling targets and calculation method put under pressure the current WMS, characterized by fragmentation in responsibilities and underperforming cost-benefit balance. In addition, the public-private governance and the increasing number in waste consortia and platforms contribute to fragment the waste streams traceability. The following study, resulting from a collaboration between University of Bologna (UNIBO), Emilia Romagna Region (ERR) and Regional Agency for Prevention, Environment and Energy (ARPAE), investigates the current panorama of plastic waste recycling system in Emilia Romagna Region (Italy). Secondary Plastics, that are no longer waste, doesn't allow the traceability by official data collection scheme. Data extrapolated from official waste databases are integrated by results coming from individual questionnaire submitted to local recyclers. The identification of the main polymers generated by a re-manufacturing process and consequently, the exploitation of economic potential into the regional market will support the future scenario planning where all plastic packaging will be recycled and recyclable.

KEYWORDS

Emilia Romagna region, plastic waste, recycling, Waste management system

INTRODUCTION

Plastics, and in particular plastic waste, are nowadays under the microscope of the whole world. The problem of marine plastic pollution has become so clear as to compromise the biodiversity but also the food chain and consequently, the animal welfare and the human healthcare (Thompson., 2015). The evidence of the impact of the mismanagement of plastic goods in the environment (Jambeck *et al.*, 2015) has captured the attention of scientists, policy makers and manufacturers (Rochman., 2016). The increasing production and consumption rates, the over packaging, the Chinese and Indian waste import ban, the lack of adequate infrastructure about waste management system (WMS) and the low consumer and producer awareness are some of the challenges to deal with. Urgent measures, regarding to a combination of preventing plastic use and massively improving waste management have been acclaimed by different stakeholders with the common goal to make a more resilient and competitive plastic industry (Ellen Mac Arthur Foundation., 2017). Plastics manufacturers and recyclers have responded through the engagement in partnerships, alliances and joint ventures (Foschi et al., 2018). European Commission has pledged itself publishing the first EU-wide policy framework on plastics (European Commission, 2018a), reinforcing existing directive on waste and introducing specific policy on Single-Use-Plastics (SUPs). In fact, legal obligations on the management of municipal waste are laid down in the *Waste Framework Directive (WFD)*, including 50% of municipal waste preparing for re-use/recycling target, to be achieved by 2020 (European Parliament and of the Council, 2008). The Directive was recently revised by the *Circular economy package* to include more ambitious targets for plastic packaging waste (PPW), reaching 55%, 60% and 65% recycling rates respectively by 2025, 2030 and 2035 (European Parliament and of the Council Directive, 2018ab). Additional purposes have also established within the *Strategy for Plastics in a circular economy*, where the Commission has set new ambitious goals by having 100% of recyclable or reusable plastic packaging by 2030 (European Commission, 2018b). Considering that the European recycling rate is estimated at 31.1% and the market on recycled plastic-based products accounts for 6%

in 2016 (PlasticsEurope, 2017), targets seems really ambitious (European Commission, 2018c). European Member States (MSs), regions and cities are invited to incorporate driving forces in policy agenda to facilitate the achievement of targets in one side and strengthen the market of recycled plastics in another. The high amount of plastic waste generated every year provides a vast field of actions to shift the demand from virgin plastics - that today accounts for 51.2 Mt (PlasticsEurope, 2018) to recycled ones. However, the current industrial recycling infrastructure is not up to the main challenge on plastics waste valorization. The increasing complexity in products design and the lack of transparency on the material composition struggle to guarantee a high quality of secondary plastic (SPs) (Pivnenko et al., 2016: Hahladakis et al., 2018: Halden, 2010). The overview on existing recycling performance supports the obstacles identification and the future scenario planning. The following study, resulting from a collaboration between University of Bologna (UNIBO), Emilia Romagna Region (ERR) and Regional Agency for Prevention, Environment and Energy (ARPAE), investigates the current panorama of plastic waste recycling system in Emilia Romagna Region (Italy). The article aims to track the end-of-life (EoL) of plastic waste and deliver a well-functioning integrated and sustainable plastic WMS, in line with the European commitments, whose directives, will have been transposed by June 2020.

1. PLASTIC WASTE MANAGEMENT SYSTEM IN EMILIA ROMAGNA REGION (ITALY)

The Italian WMS proves to be complex and heterogeneous. Municipal (waste from households and similar, also called post-consumer) and special (waste from industrial/commercial activities, also called pre-consumer) waste are managed in different ways.

According to a specific national agreement[1], municipalities entrust the waste management to Collective System or Consortia dealing with the cost coverage of post-consumer waste separate collection, sorting, recycling and eventually, disposal. Plastic waste managed by separate collection are generally packaging waste. As result of the application of the Extended Producer Responsibility (EPR) principle - where producers and importers are responsible for the waste they generate and Sharing Responsibility - where stakeholders collaborate to pursue the waste hierarchy, the National Consortium for the Collection and Recycling of Plastic packages (COREPLA) runs the financial costs about the EoL of municipal PPW. In particular, COREPLA manages the sorting of PPW for polymer (Polypropylene (PP), Low- and high-density Polyethylene (LD and HD PE), Polyethylene Terephthalate (PET)) and colour (transparent, white, coloured) and the sale of these stocks through electronic auctions to European recyclers. COREPLA system is specifically composed of:

- Centri Comprensoriali (CC) – *District Centers*: platforms where PPW waste are pre-sorted
- Centri di Selezione e Smistamento (CSS) - *Sorting Centres*: platforms where PPW are basically sorted

In order to ensure the top-line profitability of packaging, COREPLA also plays a subsidiary role for industrial/commercial PPW by providing a framework of platforms such:

- PIA - *Platforms for general industrial packaging management*
- PIFU - *Platforms for drums and tanks*
- PEPS - *Platform for Polystyrene (PS) packaging*

As described by the article 221 of the Consolidated Environmental Law, National Consortia can be combined with Independent Consortia where packaging producers and recyclers work to independently valorize their own plastic waste (Italian Government, 2006; Ministero dell'Ambiente e della Tutela del Territorio e del Mare, 2019).

As illustrated in the Figure 1 (Fig.1), Italian plastic waste are managed by a multitude of National and Independent consortia and private companies.

[1] ANCI (National Municipalities Association)-CONAI (National Packaging Consortium) framework agreement.

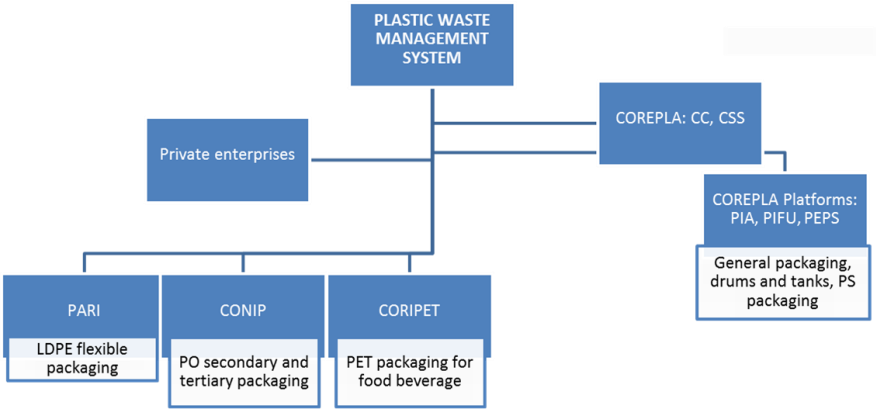

Fig 1 – Plastic waste management system in Italy

While some Independent consortia are being validated, PARI, CONIP and CORIPET, respectively specialized in LDPE, Polyolefins (POs) and PET packaging recycling, are already operative in many locations in the country. In particular, in the Emilia Romagna Region are located (See Fig.2):

- 1 of 8 companies working in PARI
- 2 of 26 companies working in CONIP
- 5 of 12[2] companies working with CORIPET

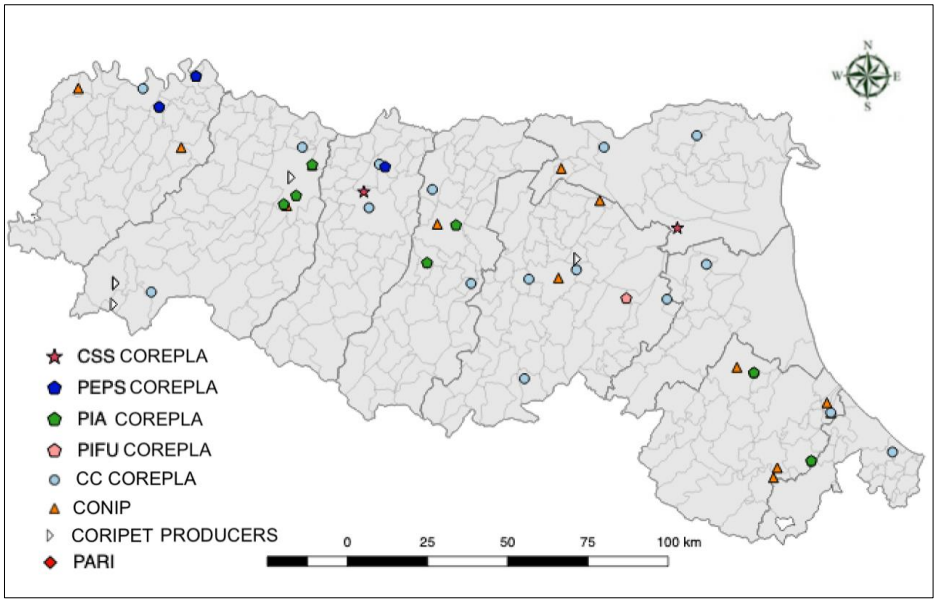

Fig. 2 – Location of plants working into the plastic waste consortia.

2. WASTE GENERATION AND MANAGEMENT IN EMILIA ROMAGNA REGION

2.1 MATERIALS AND METHODS

The work investigates both pre and post-consumer waste streams. The following table (Table 1) shows the list of European Waste codes (EWCs)[3] considered by the study.

[2] Considering the overall number of CORIPET members, only few producers are located in the Region. Recyclers work out by the regional borders.
[3] According to the WFD, waste are categorized by a code as listed in the European Waste Catalogue.

Table 1 - List of European Waste codes investigated within the study

EWC	Description
120105	Plastics shavings and turnings coming from shaping and physical and mechanical surface treatment of metals and plastics
020104	Plastics (except packaging) coming from agriculture, horticulture, aquaculture, forestry, hunting and fishing, food preparation and processing
150102	Plastic packaging (including separately collected municipal packaging waste)
160119	Plastics coming from end-of-life vehicles from different means of transport (including off-road machinery) and wastes from dismantling of end-of-life vehicles and vehicle maintenance (except 13, 14, 16 06 and 16 08)
170203	Plastics coming from construction and demolition wastes (including excavated soil from contaminated sites)
191204	Plastics and rubber coming from wastes from the mechanical treatment of waste (for example sorting, crushing, compacting, pelletising) not otherwise specified
200139	Plastics coming from municipal wastes (household waste and similar commercial, industrial and institutional wastes) including separately collected fractions

Pre-consumer waste streams include waste coming from economic and industrial activity, regarding to agriculture and food processing industry, plastic, automotive and building and construction sectors. Waste generated from waste treatment are included in the investigation and considered with an additional relevance. Post-consumer plastic waste mainly involves municipal PPW.
Data are sourced from ORSo (Osservatorio Rifiuti Sovraregionale) and MUD (Modello Unico di Dichiarazione Ambientale) datasets[4]. The regional sorting and recycling infrastructure have been identified by AIDA, OSIRIS, PARIX and AMADEUS databases. According to the main goal of the study, considering that recyclers and other customers are reluctant to reveal their internal material flows and the market of recycled plastics, a questionnaire has been submitted to local waste managers. The investigation includes data on ID, process and technology description, amount of input - output resources and their provenience and destination. Plastic waste management has been summarised by flow diagram and chart.

2.2 RESULTS

2.2.1 Plastic waste generation in Emilia Romagna Region

2.2.1.1 Plastics in Municipal Solid Waste (MSW)

On regional scale, the amount of PPW disposed by separate collection scheme accounts for 47% (132,773t, corresponding to 30kg per inhabitant) in 2017. The remains (53%) are registered into the residual waste stream where, about 35% would be recoverable, if correctly separated (ARPAE, 2018). The amount of waste produced by industrial and commercial activities directly sent to disposal (the so-called Assimilated waste) accounts for 11,729t in 2017.

The Figure 3 (Fig.3) represents the Municipal PPW generation disposed by separate collection scheme in the region. 47% of regional Municipal PPW has been produced in three provinces: Bologna, Modena and Reggio Emilia.

[4] MUD is not applied for companies with less than 10 employees.

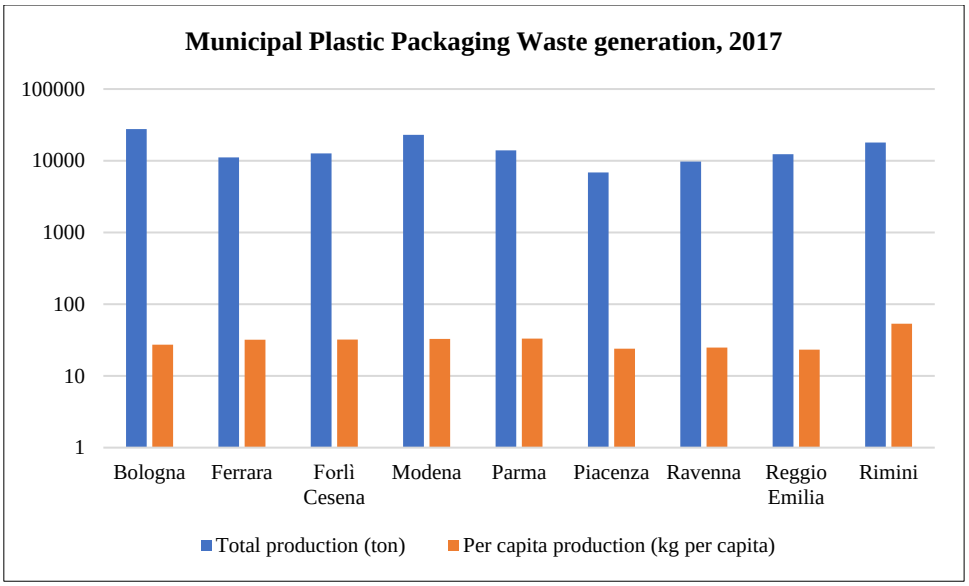

Fig. 3 – Municipal Plastic Packaging Waste generation, 2017 - Source: ORSo database

As for collection systems, 40% of the plastic is collected together with other waste in the multi-material collection. The most widespread system includes road bins, followed by door-to-door or home collection. The assimilated waste are directly sent to disposal (Fig.4).

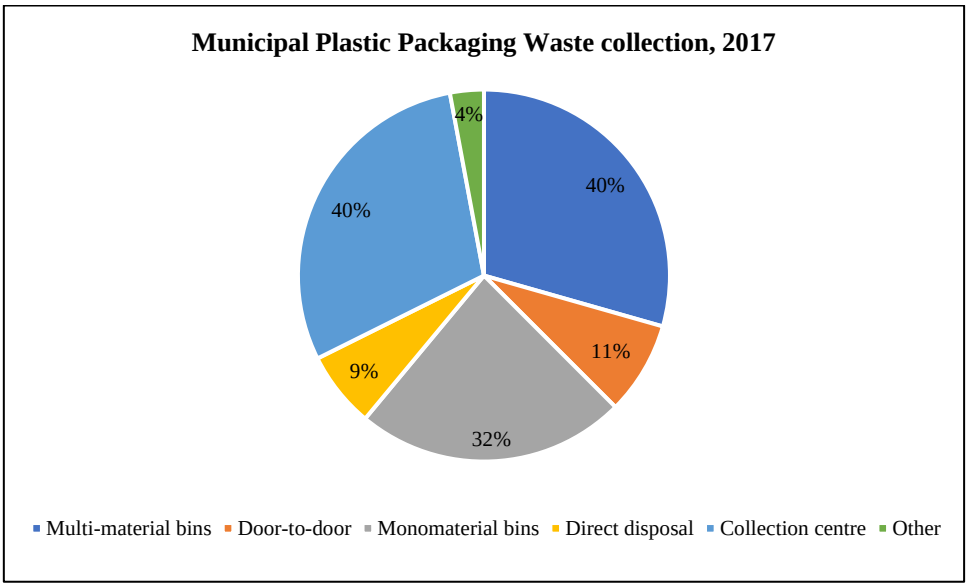

Fig. 4 – Municipal Plastic packaging waste collection, 2017 - Source: Regional waste report (ARPAE, 2018)

2.2.1.2 Plastics in Special Waste (SW)

The analysis of SW generation has been carried out by EWC and provenience.

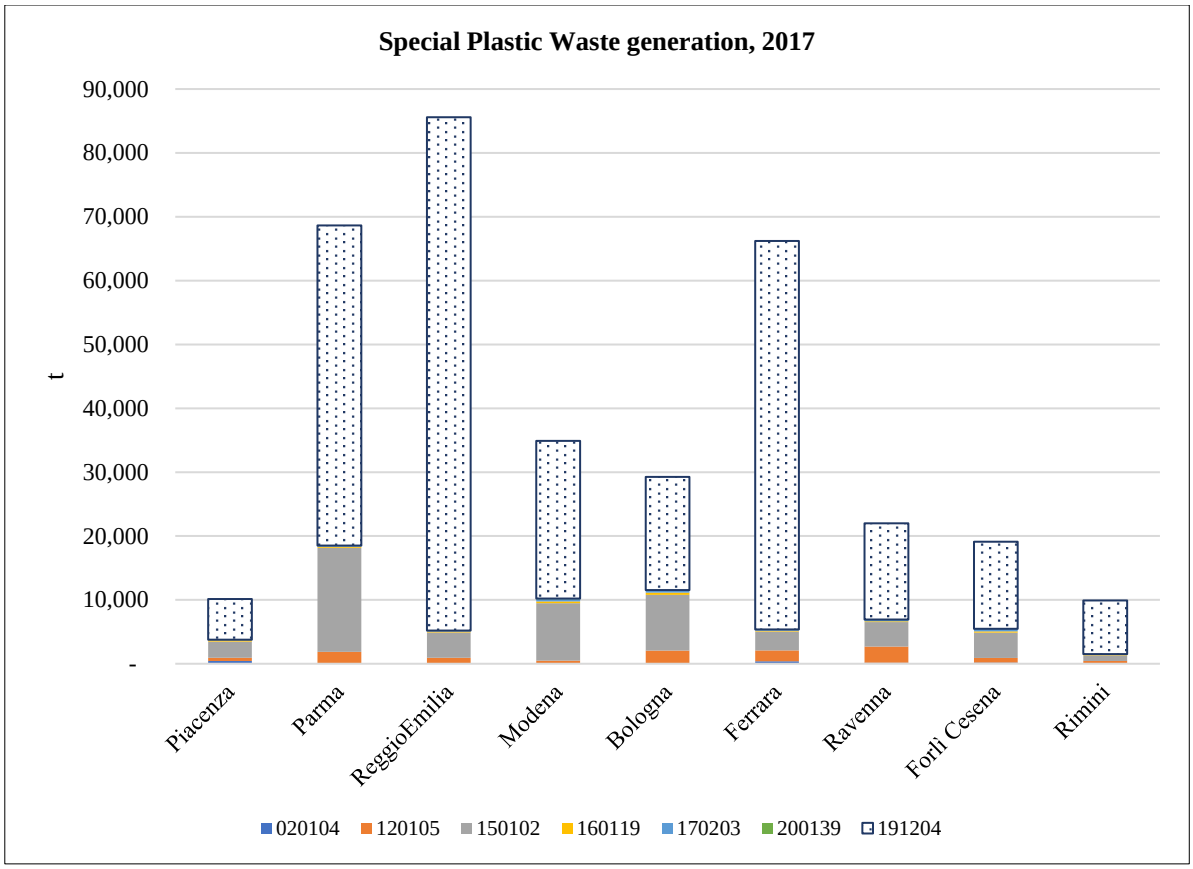

Fig. 5 – Special Plastic Waste generation, 2017 - Source: MUD database

As illustrated in the Figure 5 (Fig.5), a considerable amount of plastic waste refers to PPW produced by commercial and industrial activities. Referring to primary generation of waste coming from economic activities, a substantial stream is represented by waste classified by the 120105 EWC and generated by the plastic industry that is one of the most valuable economy in the region. Plastics pulled out from End-of-Life vehicles (ELVs) are also reasonable, accounting for 1,706 t. Agricultural plastic waste accounts for 1,297t and are mainly registered in the rural area, where the economy is based on farming. The presence of plastics in construction and demolition (C&D) waste is generally variable and influenced by a multitude of external factors (earthquakes and type of demolition, for example). The highest waste stream, codified by 191204 EWC (277,239 t), refers to scraps coming from the regional waste treatment plants.

2.2.2 REGIONAL PLASTIC WASTE MANAGEMENT

Considering waste shipment, the overall amount of plastic waste managed in ERR is about 448,539 t: 27% is produced internally and 73% is imported.

As shown in the pie chart below (Fig.6), recycling and/or recovery operations (R2-R12) treatment prevails (about 322,714 t) to waste storage to be recycled/recovered (R13) (58,270 t) and waste usage as a fuel or other energy recovery system (R1) (62,261 t). 2,464 t of plastic waste are sent to disposal activities (D2-D14) and 2,788 t to preliminary waste site before one of the operations in points D1 to D14 (D15).

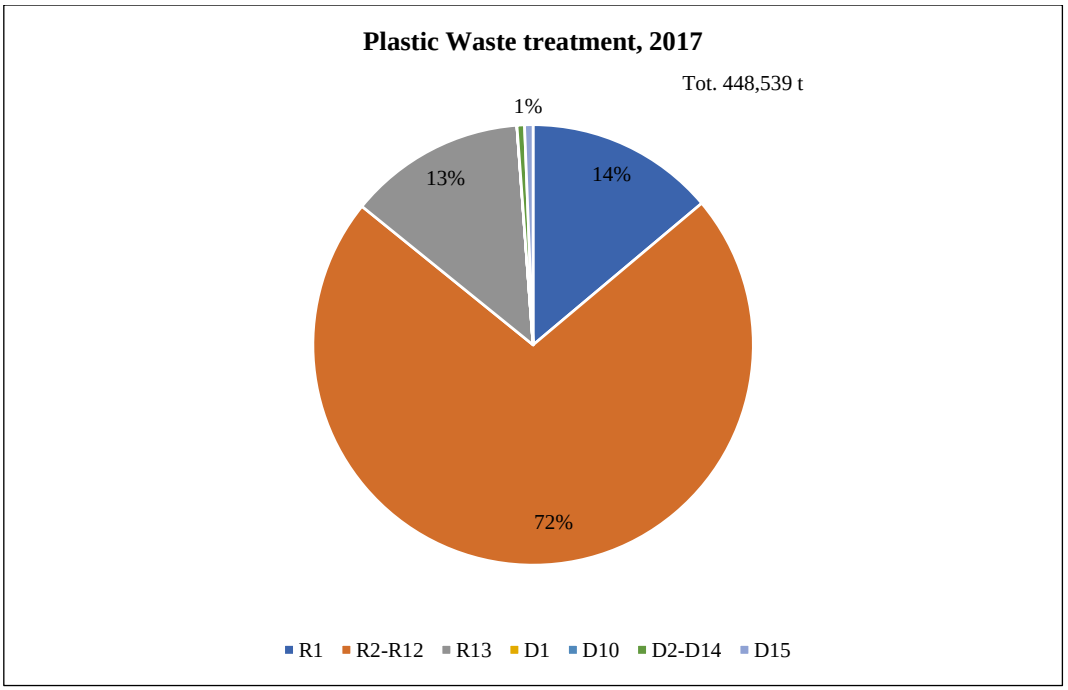

Fig. 6 - Plastic Waste treatment, 2017 - Source: MUD database

As illustrated in the Figure 7 (Fig.7), recovery and recycling rates take precedence over all type of waste treatment. The highest amount of landfill waste is represented by the management of waste classified by 200139 EWC.

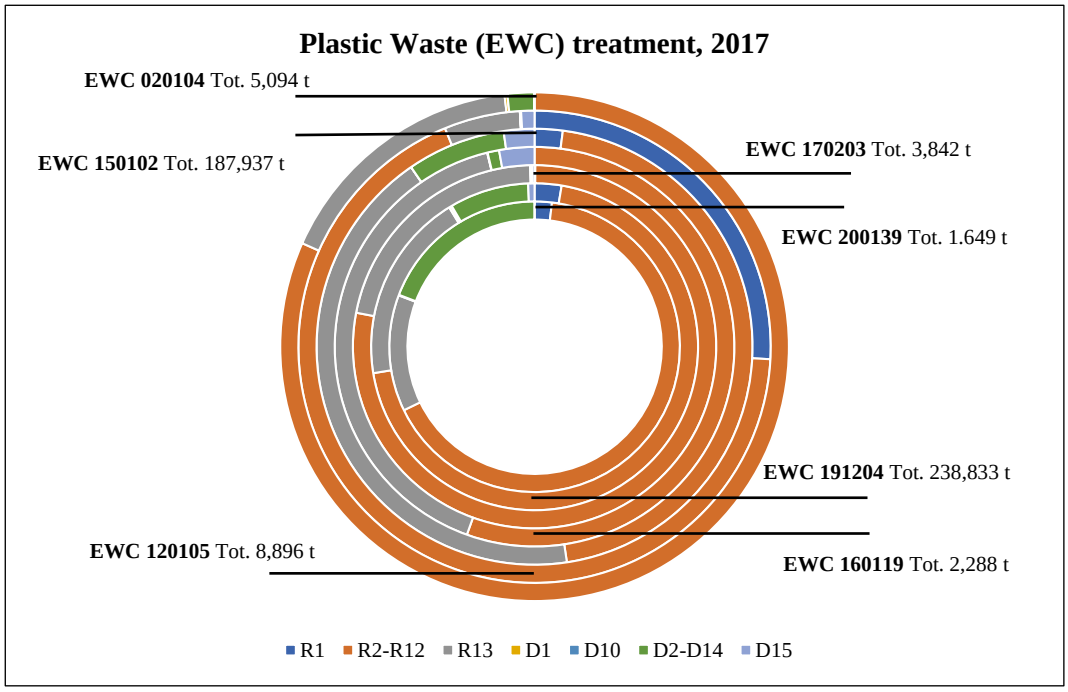

Fig. 7 - Plastic waste (EWC) treatment, 2017 - Source: MUD database

In 2017, about 190,436 t of regional plastic waste are exported. In particular, 67% are sent to national facilities, while the remaining stream is sent abroad. As of national export, Lombardia and Veneto regions receive the largest amount of regional plastic waste, respectively accounting for 44% (56,527 t) and 31% (39,346 t) (See Fig.8).

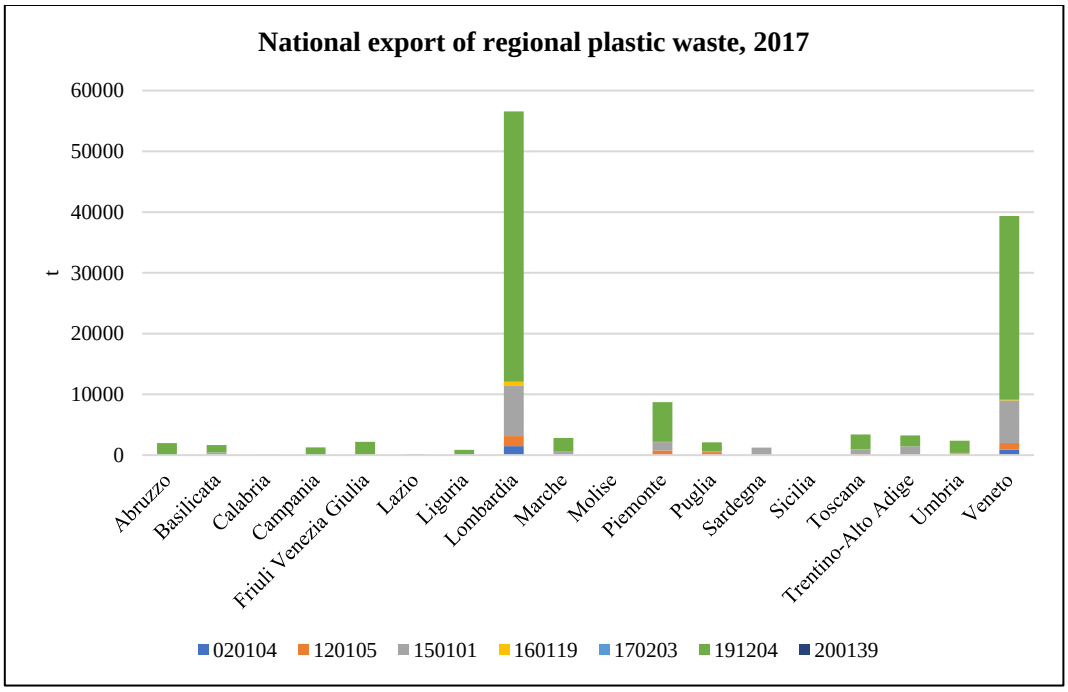

Fig. 8- National export of regional plastic waste, 2017 – Source: MUD database

In 2017, 62,549 t of plastic waste are exported from Emilia-Romagna to foreign countries. As shown in the Figure 9 (Fig.9), Austria (33%, corresponding to 20,789 t, Germany (20%, corresponding to 12,409 t,) and China (14%, corresponding to8,562 t) are registered as the main destinations.

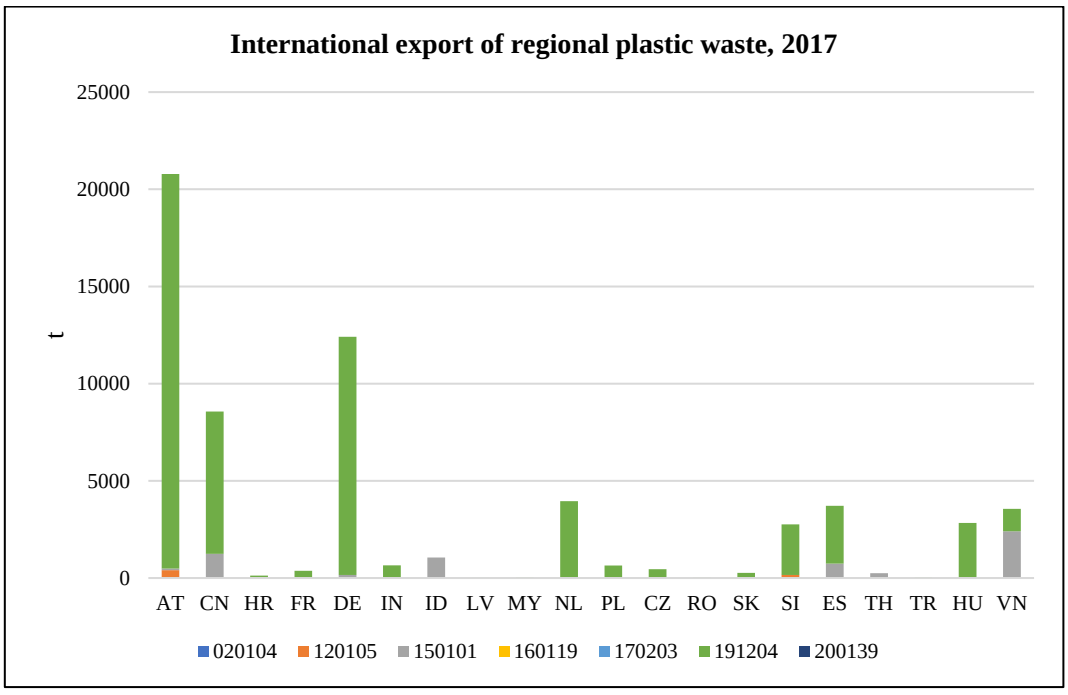

Fig. 9 – International export of regional plastic waste, 2017 – Source: MUD database

2.2.2.1 Municipal plastic waste management

As established by the article 182bis of Legislative Decree 152/06, the regional self-sufficiency of municipal waste management has led ERR to guarantee, as much as possible, the plastic waste treatment internally (Italian government, 2006). This principle has catalysed the promotion of a framework of waste operators, consortia and enterprises working in this type of waste.
About primary management, 76% of municipal PPW stream are sent to recovery (See Fig. 10). In particular, public waste operators manage 91% of the overall amount of PPW separately collected in the Region (corresponding to 121,004t). 96,711 t of separately collected PPW (corresponding to 70%) are then managed by COREPLA through a framework of pre-sorting (CSR) and sorting plants (CSS). Regarding the waste shipment, about 70% of the overall waste collected by separate scheme is sent to plants located in the Region while the remains are treated outside the regional bounders.
The recycling rate is about 22% in 2017. The relative infrastructure includes 115 recovery facilities where the hugest amount is handled by 9 recycling plants that manage about 90% of PPW separately collected.

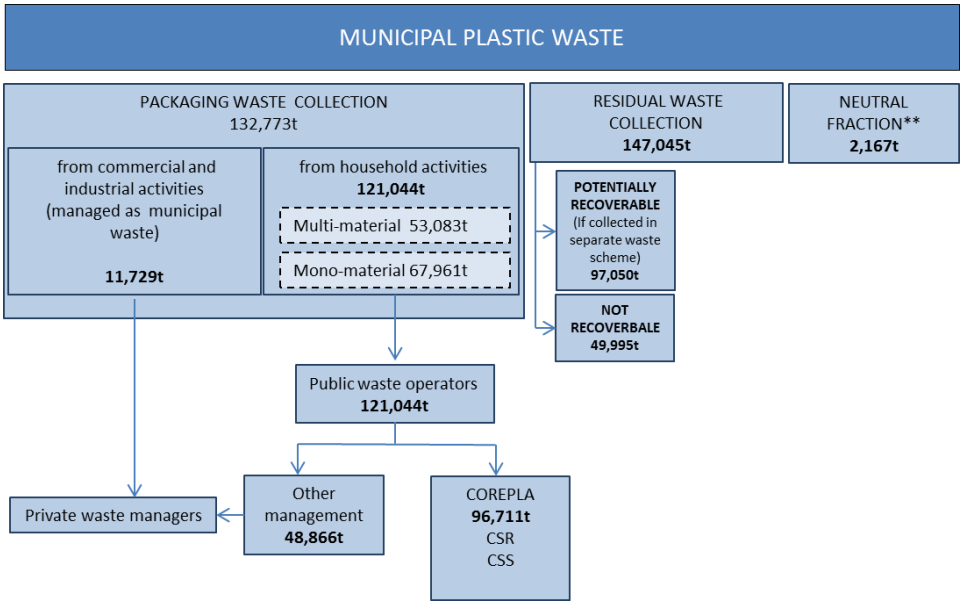

Fig. 10 – Municipal plastic waste management

**Neutral fraction refers to waste separately collected but not considered in the calculation.

2.2.2.2 Industrial plastic waste management

When waste enters into sorting and recycling facilities, waste loses information about the origin. The classification between MSW and SW is not possible. This analysis includes waste coming from agriculture, plastic manufacturing, treatment of plastics in ELVs and C&D and general waste, as codified by relative 020104, 120105, 160119, 170203, 191204 EWCs and generally called industrial waste.

In 2017, 25 regional firms handle 3,356t of waste coming from agricultural activities (EWC 020104), 10 plants of which perform complete recycling processes (R3), accounting for 295t (9%). 27 of the 38 regional plants manages plastic shavings from shaping and physical and mechanical surface treatment of metals and plastics (EWC 120105), by recycling 5,512 t out of 6,205 t (90%). The complete recycling of 920 t (72%) of plastics coming from ELVs (EWC 160119) has been performed by 15 plants in ERR. The regional plants handle waste classified by EWC 160119 are 31 and manages 1,270 t of plastics. 713 t (41%) of plastics coming from C&D waste (EWC 170203) are completely recycled by 9 of 28 regional plants. In the end, when plastic waste are treated can change the waste codification by adopting the 191204 EWC. The 25% (39,932 t) of these waste has undergone complete recycling, performed by 29 of the 53 regional plants.

In 2017, 163,338 t of plastic industrial waste are exported from Emilia-Romagna of which, 106,728 t are sent to extra-regional national plants and 56,610 t to international ones.

The management of industrial waste is regulated by a system of private companies and Independent consortia that are not obliged to send data to regional environmental agency.

2.2.3 VALORIZATION OF PLASTIC WASTE INTO SECONDARY PLASTICS (SPs)

In order to provide a micro-scale analysis of the entire recycling chain, an investigation is carried out at regional plastic recyclers. Once the firms of interest had been identified, a questionnaire has been sent via email to the plants authorized for recycling and recovery processes (classified by R3, R4, R5 and R12 waste treatment codes). In particular, the survey has included 91 plastic waste managers: 59% dealing with R12, about one third performing recovery by R3, R4, R5 waste treatment codes, while the remaining 8% are authorized for all waste processes.

The number of respondents accounts for 19%, 5 of them manages the largest amount of plastic waste in ERR. In addition, 9 respondent plants are coordinated by COREPLA as CC plants, while 2 plants handle industrial plastic packaging, as part of PIA platform. As for Independent Consortia, 3 respondent plants are part of CONIP.

The results of the returned questionnaire provide a sample view of the regional plastic recycling chain. 282 t of plastic waste classified by 020104 EWC are received by 10 regional plants, 1,280 t of waste classified by120105 EWC by 12 plants, 67,339 t of 150102 EWC by 18 plants, 149 t of 160119 EWC by 11 plants, 776 t of 170203 EWC by 13 plants, 29,982 t of 191204 EWC by 17 plants and 1,146 t 200139EWC by 11 plants.

Most of the output (62%) consists of plastics sorted by polymer and colour, as this operation is carried out by 9 respondent plants, while the remaining 38% refers to SPs re-manufactured by a complete recycling process trought the activity OF 6 plants. Just one plant includes both the outputs and 3 companies did not specify either. Output quantities are specified in Table 2.

Table 2 - Output of respondent plants

Plastic waste, by polymer		**SPs**	
Type of Polymer	**Amount (t)**	**Polymer**	**Amount (t)**
ABS	16	ABS	3
HDPE	846	HDPE	16,049
LDPE	11,831	LDPE	855
LLDPE	0	LLDPE	247
PET	1,208	PET	11,846
PP	2,905	PP	3,217
PS	119	PS	10
PVC	104	PVC	101
COREPLA mix	28,648	Other	269
Free market mix	5,748		
Plasmix	929		
Other	871		

3. DISCUSSION

The amount and the type of plastic waste generated in Emilia Romagna reflects the economy of the region where plastics represents a key material also for business. The so-called *packaging valley (and district)*, composed by more than 300 firms working in packaging and packaging machinery manufacturing, provides the biggest amount of industrial plastic waste. In addition, the phenomena related to urban growth affect also the municipal waste generation. Even if industrial waste (72%) are more than household ones (28%), ERR advances in third place for the total production of municipal waste and in first place for the production per-capita in Italy (ISPRA, 2018). Measures on waste prevention should be prioritized (Salhofer et al., 2008; Bartl., 2014). Further, the wide variety applications of plastics in the region reflects the presence in the waste stream composition, challenging the collecting, sorting and recycling performances. Eco-design should be promoted by specific actions, such as incentives and investments. In addition, the public-private governance and the increasing number in waste consortia and platforms contribute to fragment the waste streams traceability. The waste shipment makes it difficult for the lack on the knowledge about the final destination of exported waste streams.

Finally, the status of SPs, that are no longer waste, doesn't allow the traceability by official data collection scheme. It follows that the lack of technological, logistic, economic and environmental data, in an aggregated and harmonized form, gets difficult insight to provide a clear picture on recycling, making difficulties the innovation identification and consequently, the penetration of milled goods into the market (OECD, 2018). A rethinking of waste data traceability, collection and elaboration should be improved towards a more harmonized framework. The investigation here described makes efforts on capture value from raw data extrapolated from official waste databases. In order to have a wide clear picture on closing loop system, results coming from individual questionnaire submitted to local recyclers, have been stimulated the SPs mapping thus supporting the identification of the main polymers generated by a re-manufacturing process and consequently, the exploitation of economic potential into the regional market.

This intention is also supported by the recent amendment on WFD that establishes ambitious targets on recycling and a unique methodology to harmonize the calculation as well. In fact, while the Decision 2011/753/UE gave the possibility to choose among various methodologies, the *Directive 2018/851/UE* sets out a specific calculation method where recycling targets are calculated as the ratio between the amount of plastic waste sent to recycling plants and the amount of plastic waste separately collected (European Parliament and of the Council Directive, 2018a). The difficulties of reaching targets, due to lowest results given by the application of the new methodology and the establishment of higher material-specific targets, coupled with inconsistencies and statistical gaps between waste generation and treatment, underperforming collection and recycling, missing information on the market of SPs, requires increased efforts to avoid the missing of targets by considerable margins.

4. CONCLUSION

Plastics usage is dominated by few types of polymers, however, each of them are mixed with chemical substances producing a multitude framework of plastic materials and goods characterized by different molecular composition and formulation (European Commission, 2018b). Complex materials and design affect the waste valorization. Additional challenges, regarding new targets and calculation method established within the WFD amendment, put under pressure the current WMS, characterized by fragmentation in responsibilities and underperforming cost-benefit balance. Prevent at first, and redesign than, are essential building blocks to facilitate cost-effective collecting, sorting and reprocessing. The borderline in which recyclers work, make the profit of SPs more arduous. In fact, even the market is regulated by supply and demand pricing, it is not aligned with the governance of National Consortia. The new requirements established by the European Commission within the *Directive on the reduction of the impact of certain plastic products on the environment* about having 30% of recycled plastics in beverage bottle (European Parliament and of the Council, 2019) pushes more and more the usage of recycled plastics into new products. In this case, CORIPET, the Independent Consortium working on specific beverage bottles streams, covers a key role. However, although a multi-waste system feeds competitive waste market overcoming the profitability of critical plastic waste streams, the market of SPs is not so profitable. Systemic investments on eco-design and recycling itself are necessary to strive for a more local functioning market, thus contributing to strengthen the usage of SPs, reduce the demand for virgin materials and prevent littering and greenhouse gas emissions coming from incinerator and landfilling as well (Micaud *et al*. 2011). Technological and economic improvements should also be coupled by a comprehensive data system able to monitor material streams in production, consumption and circularity thus calculating prevention rate at first and recycling targets then, in an harmonized way all over Europe.

HEADINGS

• Data on Plastic waste are not harmonized. A clear picture on plastic waste management is difficult to define.

• The increasing complexity in products design and the lack of transparency on the material composition struggle to guarantee a high quality of secondary plastics.

• Investments on eco-design and recycling could support the profitability of plastic waste and secondary plastics market.

ABBREVIATIONS

Centri Comprensoriali (CC)

Centri di Selezione e Smistamento – *Selection and Sorting Centres* (CSS)

Construction & Demolition (C&D)

Countries abbreviations:

Austria (AT)

China (CN)

Croatia (HR)

Czech Republic (CZ)

France (FR)

Germany (DE)

Hungary (HU)

India (IN)

Indonesia (ID)

Latvia (LV)

Malaysia (MY)

Netherlands (NL)

Poland (PL)

Romania (RO)

Slovakia (SK)

Slovenia (SI)

Spain (ES)

Thailand (TH)

Turkey (TR)

Vietnam (VN)

Emilia-Romagna Region (ERR)

End-of-life (EoL)

End-of-Life vehicles (ELVs)

Extended Producer Responsibility (EPR)

European Waste code (EWC)

Low-density Polyethylene (LDPE)

High density Polyethylene (HDPE)

Modello Unico di Dichiarazione Ambientale (MUD)

Municipal Solid Waste (MSW)

National Consortium for the Collection and Recycling of Plastic packages (COREPLA)

National Municipalities Association (ANCI)

Osservatorio Rifiuti Sovraregionale (ORSo)

Piattaforme EPS (PEPS)

Piattaforme Industria e Artigianato (PIA)

Piattaforme Fusti (PIFU)

Plastic Packaging Waste (PPW)

Polyethylene Terephthalate (PET)

Polyolefin (PO)

Polystyrene (PS)

Post-consumer packaging waste Consortium (CONAI)

Regional Agency for Prevention, Environment and Energy (ARPAE)

Secondary Plastics (SPs)

Special waste (SW)

Single-Use-Products (SUPs)

University of Bologna (UNIBO)

Waste Framework Directive (WFD)

Waste management system (WMS)

Waste treatment code:

D1: Storage on or in the ground (e.g. landfill)

D2-D14: Disposal activities

D15: Preliminary deposit before one of the operations in points D1 to D14 (excluding temporary storage, before collection, in the place where they are produced)

R1: main use as a fuel or other means to generate energy

R2-R12: material regeneration/recovery

R13: waste storage to subject it to one of the operations indicated in points R1 to R12 (excluding temporary storage, before collection, in the place where they are produced)

ACKNOWLEDGMENTS

The investigation was carried out within the action plan of the Interreg Europe project named *TRIS – Transition region towards industrial symbiosis.* Authors would thank Maria Concetta Peronace and Annamaria Bendetti (ARPAE) for providing data and useful explanation about plastic waste generation and management in Emilia Romagna Region (Italy). Authors would like to thank COREPLA for giving data about the management of municipal plastic waste.

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