






Treatment of Port Wastes According to the Paradigm of the Circular Economy

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Abstract. The problem of the presence of waste in the marine environment has recently taken on the dimensions of a complex and global challenge. In an effort to reduce both the economic and environmental costs of managing port waste, many ports are looking for sustainable solutions for marine waste management.

Plasma-assisted gasification (PAG) is an innovative combination of two technologies, namely plasma treatment and gasification, which can be used to efficiently convert carbon-containing wastes to a clean syngas ($H_2 + CO$). The latter can be used to generate electricity directly in gas engines, dual-fuel generators, gas turbines or fuel cells. PAG provides several key benefits which allow removing all the environmental, regulatory and commercial risks typically associated with the potential eco-toxicity of leachable bottom ash produced by incinerators or other thermal processes. PAG does not produce any waste (zero waste), reduces the need for landfilling of waste, and produces a high-value construction material (Plasmarok) which is recognized as a product. All these reasons make PAG a technology capable of optimally solving waste management in ports in line with a circular economy logic.

This study is based upon the IMPATTI-NO Project (Interreg IT-FR Maritime Program 2014–2020) which implements several laboratory applications aimed at the chemical-physical treatment of the non-recyclable waste containing plastics deriving from the collection of beached waste and wastes collected by fishermen's trawls and passenger ships. To demonstrate the effectiveness of PAG for the treatment of port waste, IMPATTI-NO performs experimental tests that simulate PAG pilot plants using artificial samples representative of port waste.

This paper describes the research path developed so far and the preparatory elements that led to the definition of specifications for the sampling and collection of port waste.

Keywords: Circular economy · Marine litter · Port waste · Syn-gas

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1 Introduction

In December 2015, the European Commission adopted the Circular Economy Action Plan, whose priorities include the Plastics Strategy and its life cycle.

In the decades of economic growth that followed the war, plastic began the inexorable rise that would lead it to replace cotton, glass and cardboard as the first-choice material for consumer products. In the early 1950s, thin plastic packaging was introduced, replacing paper to protect food, and within a decade, DuPont had manufactured and sold one billion of these plastic sheets. At the same time, plastic had entered our lives so much that we didn't even realize its presence. And it came everywhere, even into space when you think that in 1969, the flag that Neil Armstrong planted on the moon was made of nylon.

The following year, Coca Cola and Pepsi began replacing their glass bottles with plastic versions produced by Monsanto Chemical and Standard Oil.

Since then, plastic production has soared to 348 million tons in 2017, with European manufacturers (EU28th Norway and Switzerland) contributing 64.4 million tons, 4.4 million more than in 2016. In the world, Europe thus contributes 18.5% to total production, just above the Middle East (17.7%), but a far cry from Asia, which now churns out half of the plastics consumed worldwide (29.4% China alone). In the main target sectors, packaging remains at the top of the list with 39.7% of the 51.2 million tons processed in 2017 in Europe; followed by construction with 19.8%, automotive with 10.1%, the electrical and electronics sector with 6.2%, home and sports and leisure items (4.1%), agriculture (3.4%) applications (16.7%).

Polyolefins are the most used plastics by European processors: all together they reach 49%, between polypropylene (19.3%), low-density polyethylene (17.5%) PE (12.3%). PVC is worth just over 10%, PET accounts for 7%, polyurethanes 7.7%, while for compact and expanded polystyrene it comes to 6.6%.

By focusing on packaging waste, 2016 Official data show a collection of 16.7 million ton, of which 40.8% was mechanically recycled, above the 22.5% expected by the current Packaging and Packaging Waste Directive, but below the 50% expected by the new targets set for 2025, 38.8% was addressed to the thermovalorizers, while 20.3% of the collected packaging has finished in landfill.

Despite the apparent positive balance sheets of plastic waste management, a pitiless estimate by experts leads to say that of the approximately 300 million ton of plastics produced annually worldwide, at least 8–13 million ton are lost at sea every year with an impact that has taken on a level that is no longer sustainable today.

2 The Marine Litter Issues

Solid marine litter (marine litter), defined as any persistent solid material produced by man and abandoned in the marine environment, derives from human activities that take place both on land and at sea. The problem of the presence of waste in the marine environment has recently taken on the dimensions of a complex and global challenge, which is the subject of attention and a cause of widespread concern at all levels.

The main terrestrial activities from which marine litter comes from are the improper disposal of waste in individual homes, the mismanagement of urban waste, the illicit disposal of industrial waste, and the tourist and recreational activities.

From the maritime side there are the loss of fishing gear (lines, nets, lobster pots, etc.) deriving from commercial fishing, the illegal disposal of waste from merchant shipping and passenger ships, pleasure boats, and fish farms.

The most frequently found materials are plastic, rubber, paper, metal, wood, glass that can either float on the surface of the sea and be transported then to the beaches or sink and lie on the seabed. Each of these can, through the mechanical action of the waves and the action of the sun, be reduced and transformed into small sizes. The longer the holding time in the sea, the more fragmentation by natural agents increases and the size of the particles decreases.

Plastics are the most representative components of this marine waste (even over 85%) found along the coasts (beach litter), on the surface of the sea (floating litter) and on the ocean floor (seabed litter). Microplastics are plastic particles ranging in size from a few microns to 500 μ , commonly found in seawater. Microplastics include a very heterogeneous series of particles that vary in size, shape, color, chemical composition and density. They can be divided, according to the source from which they come, into “primary” and “secondary” microplastics [1–3].

The interventions to reduce the pollution problem, although certainly not resolving, may include awareness campaigns on the problem, reuse, recycling, etc.

In the context of the Circular Economy Action Plan, the European Commission adopted the European Plastics Strategy in the Circular Economy Communication on 16 January 2018 [4] with the following main proposed actions:

- make all plastic packaging in the EU recyclable by 2030;
- address the issue of microplastics and oxo-plastics intentionally added in products (cosmetics, paints, detergents, etc.);
- curb the consumption of single-use plastics (through a legislative proposal).

Plastic production was estimated in 2015 to be around 270 million ton, while waste production was estimated to have reached 275 million ton.

A hotly debated issue in the scientific community – and not only – is finding alternatives in the development phase but also eco-friendly solutions for the management of plastic waste.

A first approach is to better manage the disposal phase, which is the end of life of plastic objects. The “Plastic Pollution” study analyzed plastic disposal methods throughout history. According to this study, in the 1980s, 100% of the plastic was dumped, and at that time the risk of dispersion in the environment was quite high. Incineration has taken hold since 1980, but it is only from 2000 onwards that there has been a significant percentage of recycling which now stands at around 20%, which can certainly be improved but not much. Another important aspect to consider is that glass and metals can be recycled indefinitely without losing quality or purity in the processed product while this is not the case for plastic because in the following recycles the plastic worsens its quality. It is important to know that plastics are polymers, i.e., long chains of atoms “arranged in repetitive units often much longer than those found in nature”. The longer and stronger these chains, the higher the quality of the plastic; each

time the plastic is recycled, the polymer chain gets shorter and its quality decreases. The same piece of plastic can only be recycled 2–3 times before its quality decreases to the point where it can no longer be used.

The most desirable situation would be to convert our traditional linear economic model (make-use-dispose) into a circular economy model.

3 Circular Economy

The most qualified definition of circular economy is that of the Ellen MacArthur Foundation which wrote: “The circular economy is an industrial system that is designed to be regenerative. It replaces the end-of-life concept with restoration, moves towards the use of renewable energy, eliminates the use of toxic chemicals that hinder reuse, and aims to eliminate waste through upstream design of materials, products, systems and even business models” [5].

The circular economy is defined according to three main “actions”, namely the so-called Principles of 3R: Reduction, Reuse and Recycle [6].

Figure 1 reports the Waste management hierarchy as suggested by European Commission Directives as reported in European Parliament. Amendments adopted by the European parliament on 14 March 2017 on the proposal for a directive of the European Parliament and of the Council amending directive 2008/98/EC on waste [7].

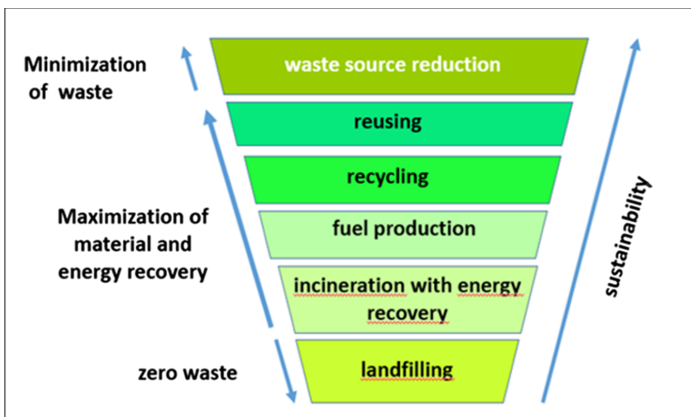


Fig. 1. Waste management hierarchy as suggested by EU Commission Directives

Although the circular economy is often identified with the principle of recycling, it should be stressed that this may be the least sustainable solution compared to the other two principles, both in terms of resource efficiency and profitability [8–10]. Recycling is limited by the complexity of materials such as plastics [11], for example. Some waste materials are recyclable to a certain point or even non-recyclable. Non-recyclable waste can be converted into energy recovery through systems of Waste-to-Energy (WtE) or Waste-to-Products (WtP) by pyrolysis, gasification, plasma gasification or can be dumped [5, 7, 12].

3.1 Waste-to-Energy and Circular Economy

WtE is a broad term that includes various waste treatment processes that generate energy (for example in the form of electricity and/or heat or that produce a fuel derived from waste), each of which has different environmental impacts and a circular economic potential [13, 14]. The main WtE processes identified by the EU Commissions [15] are:

- the co-production of waste in combustion plants and in the production of cement and lime;
- the incineration of waste in dedicated facilities;
- the anaerobic digestion of biodegradable waste;
- the production of solid, liquid or gaseous fuels derived from waste;
- other processes, including indirect incineration following a phase of pyrolysis, gasification, plasma.

Five distinct categories of processes are used as the basis for plasma waste management systems:

- plasma pyrolysis [16];
- plasma combustion (also called plasma incineration or plasma oxidation);
- vitrification of the residue of the thermal process using plasma;
- assisted plasma gasification in two variants [17].

The only technology that at the moment seems to have reached a decent level of industrialization, with better environmental performance than competing technologies based on thermal treatments (combustion or co-combustion or without direct combustion of waste) and without the defects of the more traditional incinerators and gasifiers, is the one that is called plasma assisted gasification, existing in different technological variants, mainly based on the use of “plasma torches” and in very few cases on the use of semi-submerged and submerged arc electrodes.

3.2 Plasma Assisted Gasification

Plasma plants have achieved high levels of reliability, totaling millions of hours of operation (the Westinghouse and Europlasma plants alone exceed 1,000,000 operating hours). The basic principle of this new technology focuses on the molecular dissociation (breakdown in elementary atoms components molecules) of organic waste components (and the fusion of inorganic components) operated at very high temperature within a closed reactor (plasma converter), without combustion and therefore without fumes emission and without ash production (Fig. 2).

An assisted plasma gasification plant is just a syn-gas production plant (a mixture consisting mainly of CO-H₂), and it will be the latter’s use that will determine the type of waste transformation. Synthesis gas, also known as syn-gas, is a simple blend of carbon monoxide and hydrogen. The Syn-gas can be burned to produce heat and steam, or electricity through the use of boilers, motors and turbines. This gas burns very cleanly with properties very similar to natural gas, albeit with a lower heating value.

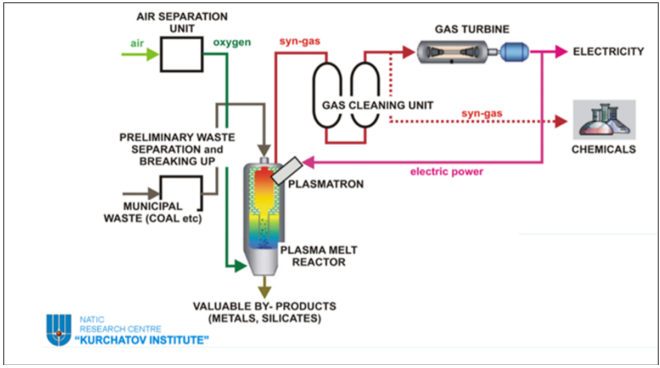


Fig. 2. Plasma assisted gasification process

Alternatively, syn-gas can be processed using catalysts and refined in a variety of liquid fuels and added value products (Fig. 3). Syn-gas can also be used to produce hydrogen and is considered a primary path to a possible hydrogen economy. Syn-gas can be upgraded into synthetic natural gas or used to produce different industrial chemicals. Gasification assisted plasma transforms various raw materials including waste into a synthetic gas instead of producing only heat and electricity. The synthetic gas produced by gasification can be turned into higher-value commercial products such as transport fuels, fertilizers, chemicals and even to replace natural gas.

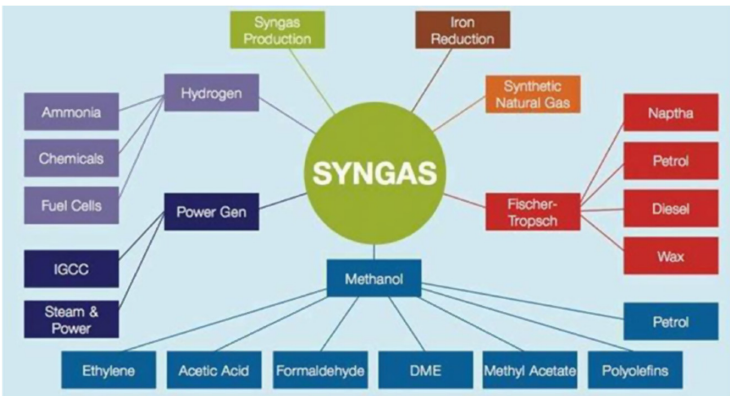


Fig. 3. Alternative use of the syn-gas

Thermochemical conversion of biomass and urban solid waste is being developed as a tool to promote the idea of the energy system without fossil fuels. In urban solid waste management, gasification does not compete with recycling, and also improves recycling programs.

Pre-processing and post-processing must increase the amount of recyclable materials in the circular economy. Since the process is endothermic, the high reaction temperature is provided by an external source of energy consisting of a plasma (ion mixture at 15,000–20,000 °C) activated by a voltaic arc. The result of the process is a synthetic gas purer than methane, predominantly hydrogen and CO with about 1/5 nitrogen and light hydrocarbons (thanks to sophisticated process control, this composition of the synthetic gas remains virtually constant, regardless of the type of waste destroyed: paints, tires, plastics, wood, fabrics, sewage sludge, etc.).

3.3 WtE System Integrated with a Plasma Gasification Thermal Process

In general, the energy exploitation of the syn-gas can be carried out according to two alternatives:

1. the direct combustion of syn-gas as produced (or after mild treatments) in conventional combustion systems placed downstream of the gasifier (“thermal” conversion);
2. the use of syn-gas in unconventional installations, such as internal combustion engines and gas turbines, after thrust purification (“electric” gasification).

In the “thermal” gasification, the syn-gas produced is combusted without undergoing (or after only very gross) purifying treatments aimed at eliminating the dragged powders, tar and other pollutants present (HCl, H₂S, SO₂, etc.), in order to generate electricity through the production of steam. Exhausted fumes must of course be treated downstream from combustion, as is the case in a traditional waste incineration plant. This solution does not differ substantially from the direct combustion of waste in that it takes place in virtually two successive stages without almost continuity. The differentiation becomes almost formal in that it is not possible to physically separate the gasification phase from that of the final combustion of the derived gas, so the treatment is configured as an incineration and as such, rightly, subject to all the requirements and regulations applicable to it.

In the “electric” gasification, the two phases of production of the derived gas and its use in turbine or internal combustion engine to produce electricity are quite distinct. It is this solution that, at present, has greater potential for development, because, on the basis of what has already been experienced with coal and some biomass, the production of a gas fuel destined to be used in a turbine allows the adoption of combined cycles for the production of electricity.

Ultimately, plasma reactors do not determine the combustion of waste but the simultaneous sublimation, pyrolysis, gasification at very high temperature of organic materials (natural or synthetic), the melting of metals and the melting-vitrification of inert materials; they are designed to maximize the conversion of waste in charge to syn-gas, consisting mainly of carbon monoxide and hydrogen, with various alternative uses. They also have several important features:

- they use very limited quantities of air and oxygen (in special cases nitrogen or argon) and operate in a reducing environment, in a closed reactor and in slight depression to avoid uncontrolled gas leaks;

- they do not produce ash or unburnt, while the particulates, dust and sludge from the syn-gas purification are almost always returned to the reactor and vitrified with periodic specific treatment campaigns under controlled process conditions;
- 1 ton of MSW as it is, gasified in plasma reactors, produces between 800 and 1200 Nm³ of syn-gas (the volume/ton varies according to the quality of the waste and the technological variant of the reactor);
- 1 ton of MSW generates about 180–190 kg of recyclable glass slag (with volumes, if compact and untreated, of just 0.085–0.095 m³, and density of 1.8–2.2 tons/m³). The glass slag has proven to be not very leachable. Being an inert, it is recyclable for many uses in the construction sector;
- the syn-gas is purified at high temperature and then also undergoes “quenching” treatments (very rapid reduction of temperature) and further cold purification; the treated gas is used for the production of electricity and steam (combustion in a gas turbine in a combined cycle with a condensation or derivation and condensation steam turbine), and/or for the production of precursors for the chemical industry (methanol, ethanol), and/or for the separation of ultra-pure filtration hydrogen;
- hydrogen from syn-gas can be used in petrochemicals, in the food industry, in buses and electric cars powered by hydrogen fuel cells, in innovative cars with liquid hydrogen or compressed hydrogen gas, in research laboratories and special industrial applications;
- the CO₂ produced is so pure that it can be compressed and reused directly as an additive for carbonated drinks, or returned to the combustion chamber;
- emissions into the atmosphere from possible combustion of the syn-gas in the turbine or boiler are very low due to the fact of burning an already highly purified gas;
- investment costs vary from 1,550 €/ton annual capacity) for very small mobile units (1,500 ton/y) to be moved to sites to be reclaimed, to 900 €/ton annual capacity) for medium-small fixed units (30,000 tons/y), at 325 €/ton annual capacity) for high-size fixed systems (650,000 tons/y) made up of medium or medium-small size reactor batteries;
- the systems are characterized by extremely high flexibility with respect to the charging materials.

4 The Experience of the IMPATTI-NO Project: Verification of a Gasification System with Assisted Plasma on a Pilot Plant

The IMPATTI-NO project, which started in 2018, implements joint action plans for the prevention, reduction and sorting of waste and wastewater in ports. In this context, it aims to identify the best waste and wastewater treatment technologies in port areas. Starting from the characterization of the waste and effluent present in the ports involved, IMPATTI-NO carries out a series of experimental campaigns on multi-versatile pilot plants, for the treatment of waste and effluent in four test ports, in order to identify the best technologies to be applied to each one in consideration of the treatment costs and the final economic value of the manufactured product.

4.1 The Phases of the IMPATTI-NO Project

Starting from the analysis of port waste, the chemical-physical characterization of the collected samples is carried out (5–10 kg each):

Chemical characterization:

- immediate analysis (humidity, ash, MV, fixed C);
- elemental analysis (C, H, O, N, Cl, S);
- calorific value (PCS and PCI);
- analysis of the ashes.

Thermogravimetric characterization:

- TGA (thermo-gravimetric analysis) up to 1000 °C in an air atmosphere;
- TGA (thermo-gravimetric analysis) up to 1000 °C in a nitrogen atmosphere.

These characterizations are intended to evaluate the thermal behavior of the plastic material to be used for gasification tests with plasma on a pilot plant. Furthermore, an experimentation is carried out which consists in the treatment by means of assisted gasification with plasma of waste materials of port origin with a high organic content.

The experimentation is divided into 2 phases:

1. syn-gas production by gasification in a rotating drum reactor in an atmosphere enriched with O₂;
2. treatment of the syn-gas produced by the previous gasification phase, in the plasma torch to produce purified gas that can be used in a gas turbine (WtE) or to obtain chemical products (WtP).

The first phase aims to define the optimal conditions of the gasification process and to determine the composition of the syn-gas and any char produced by the gasification phase. These analyzes will aim to identify the appropriate process parameters (heating speed of the incoming material, temperature, atmosphere) of the gasification and the most suitable loading conditions in the system (for example of the materials of the loading system). The pilot gasification plant must be suitably equipped to adapt the incoming atmosphere control system to measure (through thermocouples) the temperature inside the reactor. The syngas produced will pass through a system of condensers which will remove the condensable fraction (water and tar) which will be subjected to chemical analysis. The gasification reactor will be equipped with a differentiated oxygen injection system (enriched air) which, ensuring a high degree of mixing between reagents, allows to achieve faster reaction kinetics and therefore a higher yield in terms of the quality of the syn-gas produced compared to traditional rotating drum reactors.

The second phase of purification of syn-gas through plasma torch treatment has the purpose of determining the composition of the gases produced by this treatment to establish their possible energy use in the turbine. The adoption of the plasma torch technology is the right choice for the reduction of the danger of the syn-gas and for its purification, as it is possible to obtain a very rapid heating of the input syn-gas, a necessary condition for the atomic dissociation of the initial molecules (flash pyrolysis). With this system it is possible to carry out the “flash pyrolysis” at very high

temperatures that allow the immediate and complete decomposition of gases and/or liquids into elementary molecules. This technology is particularly suitable for the thermo-destructive disposal of port, urban and special plastic residues.

In particular, the activity involves checking the following parameters:

- reactive kinetics;
- distribution of heat treatment products (and by-products);
- characteristics of syn-gas.

From the results of these tests it will be possible to estimate the treatment costs and the final economic value of the product made. Finally, a technical-economic comparison will be made between the conventional technologies of gasification of plastic waste and the most innovative gasification technology assisted with plasma torches for the purification of syn-gas.

This paper describes the waste collection and sampling process developed within the IMPATTI-NO project.

5 The Waste Sampling Procedure in the IMPATTI-NO Project

In the IMPATTI-NO project, the solid waste accidentally collected by fishermen during normal fishing activities is collected in special containers (e.g. a bin or a big bag), placed on board the boats participating in the fishing-for-litter initiative, and the waste transferred ashore in special structures without any economic burden for the fisherman. This practice has already been operating successfully since 2005 in various marineries, especially in Northern Europe: Scotland, Holland, Belgium, Germany. One of the problems for which this system is not widespread in Italy is the lack of adequate transfer points in the ports and areas where fishing vessels moor, as well as a deficiency in the collection and disposal or recycling processes.

To give the tests carried out on a pilot gasification plant with assisted plasma a certain reproducibility, artificial samples that reproduce the average results of the campaigns carried out by other research groups were built. The protocol used has been developed based on the one created in the Marine Strategy Framework Directive (MSFD Technical Subgroup) by the Marine Waste Technical Group, following a standardized method that allows the comparison between the data collected by anyone who uses it worldwide.

5.1 Preparation of Samples from Marine Waste and from Waste Produced on Board Ships

The sampling involves the preparation of 5 samples, of 5 kg each, in pieces not exceeding 50 mm, coming from waste so diversified by type A, B and C:

- Type A: N°1 sample prepared from beach litter material.

- Type B: N°2 samples prepared from the material collected by fishermen during normal fishing activities and delivered in “dismountable bins” (or other containers for waste collection) made available in the ports by the Port Authority:
 - 1 sample free of metal and glass (recyclable) but with all plastics;
 - 1 sample free of metal and glass and recyclable plastics.
- Type C: N°2 samples prepared from non-recyclable dry waste from merchant and civilian ships that operate the separate collection, thus consisting respectively of:
 - N°1 representative sample of the dry non-recyclable waste as it is;
 - N°1 sample consisting only of the non-recyclable plastic present in the dry non-recyclable waste.

Each of these prepared samples is accompanied by a certificate of analysis which reports:

- moisture analysis, Ash, MV, fixed C;
- elementary analysis (C, H, O, N, Cl, S);
- heating power (PCS and PCI);
- analysis of the ashes.

5.1.1 Preparation of the Sample of Type a from the Material Collected on the Beaches

In order to obtain from the experimental tests results that have the possibility of being extended to general considerations, it is necessary that the packaged waste samples to be sent to the research institute for subsequent experiments approach a material composed of categories and compositions that respect as much as possible those of an average representative sample of waste collected on the beaches. In the circular economy, only that part of non-recyclable waste must be subjected to the WtE system.

As regards the identification of the recyclable plastic from the total plastic present, samples of plastics are sent to a specialized recycling center to evaluate their recyclability. To facilitate sampling, reference is made, for the identification of the part of the recyclable waste, to the provisions of the Municipalities for separate collection:

- recyclable plastic: plastic bottles (water and drinks), containers for liquids (shampoo, detergents, etc.), yoghurt jars, trays and transparent films for food, polystyrene, saucers, cutlery and plastic glasses, bins of any size, polystyrene for packaging. Toys, basins and chairs are not recyclable.
- recyclable metal: beverage cans (beer, soft drinks, etc.), food cans (peas, tuna, peeled, etc.), metal cables and wires. They are not recyclable: empty cans (shaving foam, hair spray, etc.).
- glass: bottles, jars and containers. They are not recyclable: ceramic and porcelain shards (of plates or cups), mirrors, light bulbs, neon tubes, oven dishes.

Figure 4 summarizes the procedure for packaging the sample.

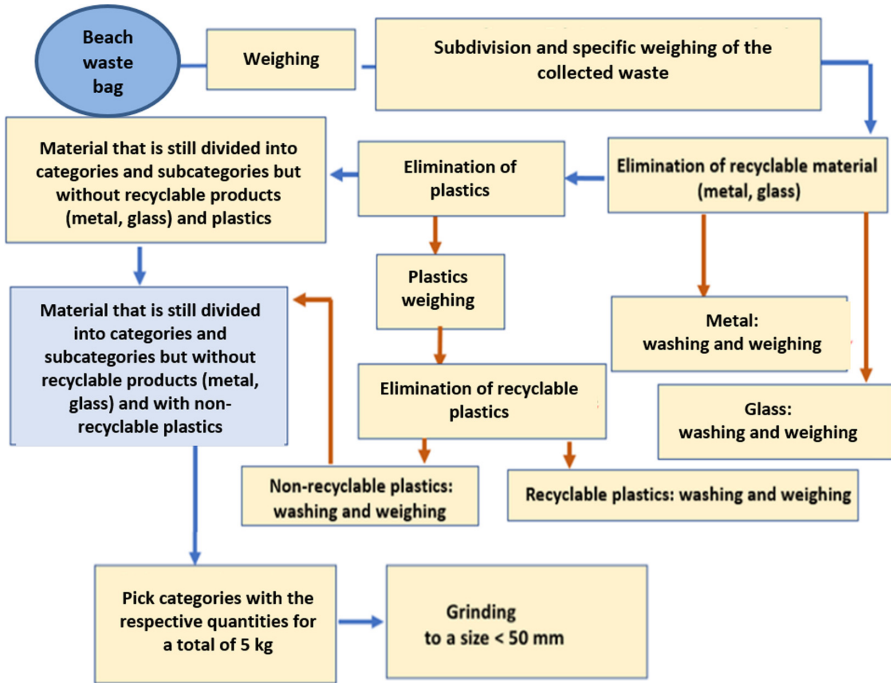


Fig. 4. Sample preparation flowsheet from the material collected on the beaches

5.1.2 Preparation of the Samples of Type B from Material Collected at Sea

The term marine litter is defined as any persistent (durable) solid material produced by man and abandoned in the marine environment. The waste arrives at sea both from land sources (bad individual habits, incorrect management of urban waste, lack of wastewater treatment plants, illicit disposal of industrial waste, floods, etc.) and from marine sources (illegal disposal of the waste produced from passenger ships, merchant ships, platforms). Commercial fishing, mussel farming and fish farming also contribute to the production of solid marine litter when fishing gear (lines, nets, lobster pots, etc.) is accidentally lost or voluntarily disposed of at sea. These solid waste (bottom material), accidentally trapped by nets (especially bottom trawls) during normal fishing activities are collected by fishermen in special containers (e.g. a bin or a big bag) placed on board the boats (at least those participating in the fishing-for-litter initiative), and subsequently transferred to land in special structures (demountable bodies) without any economic burden for the fisherman.

For the preparation of the Type B samples, coming from the material collected by the fishermen at sea and discharged in detachable bins made available in the ports by the Port Authority, reference is made to the products of the different categories (plastic, rubbers, metals, glass, ceramic, concrete, clothes, wood, etc.). The average analytical results of the first experiments obtained by the “Experimental Project Fishing for Litter” are used for preparing the samples.

5.1.3 Preparation of the Samples of Type C from Non-Recyclable Dry Waste from Merchant and Passenger Ships that Carry Out Separate Collection

The samples prepared from the non-recyclable dry waste fraction from merchant and passenger ships that operate the separate collection are made up as follows: the first representative sample of the non-recyclable dry waste as it is (C1), the second sample consisting only of non-recyclable plastic present in the dry non-recyclable waste (C2). Both samples must be ground to a size not exceeding 50 mm.

To obtain a convenient product analysis, it is necessary to take a quantity of dry waste not less than 100 kg. This quantity is placed on a screening surface with 20 mm mesh, in order to separate the smaller materials, which are collected in a special tarpaulin in PE below, and which are subsequently collected in the dedicated container. We then proceed to the manual sorting of the product fractions by placing them in their respective pre-calibrated containers. At the end of this operation, the waste belonging to the different classes is weighed, using a suitable weighing system. To remedy the difference in weight between the sum of the individual fractions and the overall weight of the class previously determined, due to the evaporation of the material during sorting or the loss of small materials, the percentages relating to the individual fractions are referred to their sum once the sorting has been carried out and not at the initial weight. Therefore, the total weight (P_{tot}) of the sample will be given by:

$$P_{tot} = \Sigma (\text{product fractions after sorting})$$

In the 5 kg type C1 sample, all the categories are present with the respective % contained in the dry waste non-recyclable as such. The preparation of the 5 kg C2 sample, in which only the non-recyclable plastics are present, is prepared by taking this quantity (5 kg) from the plastic category.

6 Final Remarks

This paper has described the first phases of the IMPATTI-NO project which has the objective of analyzing the costs of collection, transfer and treatment of marine and port wastes, the “economic” benefits resulting from the cleaning of the sea and coasts, and the economic value of the final product of the treatment. The final scope of the project is to identify, within the test area (Upper Tyrrhenian area including Sardinia and Corsica), the most advantageous logistics solution for the treatment of marine litter. The choice of the logistics solution will depend on the volume of waste produced by each port, its location (the census of waste volumes has already been completed within the project), the investment and management costs of the treatment plants, and the location strategy adopted.

The waste sampling phase is currently underway, the study is expected to close in autumn 2021.

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