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Municipal solid waste management in island communities: existing experience and implementation possibilities for South Aegean Islands

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Abstract

Solid waste management in island communities is triggered by the limitation in the availability of resources, which in combination to the small amounts of wastes produced, renders the selection and sizing of the appropriate methods and infrastructures very challenging. Certain complexity to the decision-making adds also the lack of advanced infrastructures which in most islands are only limited to sanitary landfills and the time-varying MSW production load following the related touristic infusion. The current national policy foresees the creation of local facilities with emphasis in the recovery and recycling of materials, but still the technology selection and the model of MSW locally applied needs further exploration. In view of that, the aim of this paper is firstly to review the technologies and models used in MSW management in isolated island areas around the world and secondly to acknowledge any possible technology and know-how transfer that could be used in the case of Greek island regions. The paper concludes with a community-based solution suggestion: a set of MSW facilities for a group of islands, allowing to operate on a synergetic and economically viable basis, even during the winter period that the waste faction is very limited.

Keywords: Municipal solid waste management; island communities; scale of capacities; synergetic model

1. Introduction

Sustainable Municipal Solid Waste Management (MSWM) remains still a challenging issue globally both for policy makers and engineers to tackle. At the level of policy making, the high recycling and recovery goals (50% by 2020) remain unmet (Eurostat, 2018), by almost half of the EU Member States (MS), acknowledging gaps and challenges that must efficiently be addressed, imposing the need for state-level action plans. That also is reflected in the EU toolbox (Circular Economy package and European Green Deal) that foresees a "resources' efficient and competitive economy" by improving waste management practices, stimulating recycling and innovation in materials management, and limiting the use of landfilling. The difficulty in competently adopting the EU policy packages is that not only that for each MS a particular roadmap for the efficient identification, collection and management of MSW fraction is required, but also that within each country, due to different climatic conditions, type of wastes produced and stored, no straightforward solution may be applied.

Especially in the case of island regions with many small islands like the one of South Aegean Sea in Greece, their unique environment, isolated and vulnerable nature in alliance with the local cultural, social and environmental values that must be safeguarded, mandates customisation of the MSWM applied solutions. In addition, islands (especially the small sized ones) are also challenged by the tourist variable load for almost a quarter of the year, which imposes another challenging issue for decision makers to be address. In Greek islands sustainable management of MSW is very important considering that, at present (2021), the islands lack of available infrastructures which in most cases are only limited to sanitary landfills, thus undermining the recycling and recovery perspective and respective goals. As to that, the current national policy foresees the creation of local facilities, trying to keep up with the national goals set.

But still which technology to select and which MSWM model is the most appropriate for each island, is a triggering issue, that needs further exploration and wider understanding. So the aim of this paper is to overview the MSWM systems and practices in island regions around the world and introduce a conceptual model, based on circular economy principles for the south Aegean islands.

The proposed solution foresees the creation of sub-groups of islands in which waste stream circulation will be enabled, facilitating the conditions for local green entrepreneurship as well. Also it highlights that it is possible at island-level to manage their MSW fraction economically, allowing replicability and transferability of this model management at global scale.

2. Waste Management Practices in EU Islands

For the purpose of the study Malta and Madeira Azores MSWM practices will be analysed as typical (small-to medium) European islands that have intense tourist activity, isolated character, thus relying only to the location infrastructures for MSW treatment.

2.1 Malta

The Maltese Islands are made of an archipelago of six islands of a total area of 316 km^2. Three of the islands are uninhabited, whilst the majority of the population lives on the largest island, that is, Malta. The islands sustain a very high population density (highest in the European Union (EU) and third in the world) which in the 2011 demographic review reached an average of 1327 persons per km^2. The overall treatment of MSW (data of 2014 and 2019) in Malta in 2014 is characterised by high landfilling rates, ~90% and low recycling rates ~11.0 %, as a reflection of the local small scale recycling market (European Environment Agency, 2016a, National Statistics Office of Malta, 2020, Camilleri-Fenech et al., 2018). Malta, targeting to achieve economies of scale in recovery and recycling of waste in accordance to the EU MS, in 2016 put in force the North Waste Treatment Plant (MNWTP) a mechanical and biological treatment plant to treat mixed municipal waste also providing a solution for two livestock sector waste streams which have an increasing impact on the island – manure and chicken dung (76,000 ton/year municipal solid waste 47,000 ton/year bulky waste 35,000 ton/year manure 4,000 ton/year chicken dung (European Biogas Association, 2019)). Malta' s rest MSW units also include the Gozo transfer station, a Material Recovery Facility (MRF) and the thermal treatment facility situated in Marsa which consists of an incinerator that uses heat to process abattoir waste, clinical waste and other hazardous waste streams. It also includes an autoclave plant that treats animal tissue waste prior to the incineration process and Engineered landfilling. So, Malta currently applies a combination of thermal and mechanical process seeking to eliminate the waste landfill fraction, by applying good and integrated practices.

2.2 Madeira and Azores

Madeira is one of Portugal's two autonomous regions. It consists of the islands of Madeira and Porto Santo, which have at total a population of 254,368 people according to 2017 statistics (249,195 and 5,173 inhabitants, respectively). Madeira has a higher population density than the rest of the country (around 300 people per km^2), with around 75% of the population residing in only 35% of the territory. Madeira is a popular tourist destination, with many of the island's accommodations concentrated in the south. In contrary to the country's figures (European Environment Agency, 2016b,(Zero Waste Europe Association, 2019), Madeira has a 140,000-tonne-per-year waste incineration plant (data of 2017). Since this is more than the total amount of municipal solid waste produced, the incineration facility has been running at less than its full capacity. Madeira compensated it by deactivating its composting facility many years ago, requiring all waste to be incinerated.

Azores is Portugal's second autonomous territory, consisting of nine islands and a population of 246,772 people. The island of São Miguel (where the region's capital, Ponta Delgada, is located) has 137,699 residents, while Terceira, the second largest island, has 56,062 residents (2011 data). The nine major islands of Azores are divided into three groups: Flores and Corvo to the west, Graciosa, Terceira, São Jorge, Pico e Faial in the centre, and São Miguel and Santa Maria to the east. The MSW policies are listed as follows: Terceira has a decreasing rate in the MSW produced in recent years (33,179 tn in 2017, (Zero Waste Europe Association, 2019)) a figure quite smaller than the local's incinerator's capacity (40,000 tn) allowing the incineration of 62% of the MSW fraction produced with the remaining sent for selective recovery (30%) and landfill (8%) (Patrão Costa Margarida et al., 2008). This is also the case that the incinerator causes weak recycling performance, and it disincentivizes the introduction of appropriate steps to meet the EU's recently adopted ambitious circular economy goals. In São Miguel the per capita municipal solid waste generation has risen in recent years, reaching 81,668 tn in 2017 (Zero Waste Europe Association, 2019), slightly exceeding the proposed incinerator's capacity (72,000 tn). The local recycling rates are also low (21% in 2017) with only the 5% of organic material being recovered whilst the 74% of the produced MSW landfilled. Again here an incineration plant is foreseen, a plant to be EU funded.

2.3 Concluding remarks

Reviewing the MSWM of the selected European islands it has been evidenced that: a) there is no standard/typical waste management model, b) each country, each cluster of islands and/or each island separately implements its own MSWM system that meets the local needs, and c) most importantly, there is no integrated MSWM system that foresees the goals of circular economy.

3. Waste Management Practices in Greek Islands

The South Aegean Archipelagos covers an area of 5,286 km^2 (4% of the country's surface) with a local population of 312,293 (census 2011) inhabitants. It consists of the island complexes of Cyclades and Dodecanese and includes 79 islands (of which 52 are inhabited) and 178 rocky islets. In contrary to EU average, the South Aegean islands have a lower population density with approximately 65.5 people per km^2 but with a very high tourist visiting ratio resulting almost 20 foreign visitors to each inhabitant (~60,000 in Cyclades and ~105,000 in Dodecanese in 2014). The average area per island quite varies in the Cyclades complex (from ~430km^2 Naxos which is the largest to less than 100km^2 like Kythnos) and similarly in Dodecanese but with larger variations (from 1400km^2 Rhodes (largest) to less than 100km^2 like Astypalaia). Concerning the MSW production, Cyclades complex, with an area 2,572 km^2 and 120,559 inhabitants

is responsible for 102,727tn/year while Dodecanese complex, with an area 2,714 km^2 and 191,734 inhabitants is responsible for 162,152 tn/year.

3.1 Existing practices, policies and state scenarios

MSWM in South Aegean Archipelagos, in accordance to the mainland, is characterised by high landfill rates (more than 80%) and limited composing and recycling practices. In almost all Greek islands there is a sanitary landfill in operation nevertheless there are islands that may have an uncontrolled site. Concerning recycling, good practices are applied at some islands, including also the latest technological advancements, i.e. smart waste bins that act complementary to good initiatives: i.e. no plastic initiative in Santorini, but again in terms of infrastructures there exist only few MRFs, whilst at the moment there is no provision for circular economy principles' integration. The Regional Plan Waste Management of the South Aegean Region (PESDA, 2016) sets high goals for the MSWs: more than 80% recyclable materials to be collected in separate bins (paper, glass, metal, plastic) and 40% of bio-waste including food scraps and green waste. That will lead to a material recovery of over 72% with the remaining 28% to be disposed in landfill. The policy plan also foresees the creation at each island of a green point (whereas all the recycling collection facilities (bins) including the special streams i.e. batteries will be present), waste transfer stations of presorted recyclable materials, small mechanical composting units, sanitary landfills, restoration of uncontrolled sites, and special provision for other waste streams i.e. end-of-life vehicles etc. Also in PESDA two implementation plans/scenarios are considered concerning the MSWM facilities: a) the basic scenario which assigns in each island a set of infrastructures as listed beforehand, and also foresees the construction of 4 MRFs for mixed wastes in Syros, Naxos, Rhodes and Kos (serving also some nearby islands), while b) the second scenario "the alternative" as quoted, keeps the same infrastructures per island, giving emphasis in the pre-sorting of recycling fraction in each island and in the upscale of the MRF units to host larger quantities. In both scenarios the remaining residues from the processes are directed to the islands that have sanitary landfills. The costs of the plants and their respective capacities for the two PESDA scenarios are summarised in the Table 1.

Table 1. Investment cost for integrated MSWM in Cyclades and Dodecanese under the two scenarios of PESDA (2016)

Island Complex	Capacity of MRFs	Investment Cost
Cyclades (Basic Scenario)	Syros (5,800 tn /y) Naxos (5,300 tn /y)	79,290,610€
Dodecanese (Basic Scenario)	Rhodes (39,300 tn /y) Kos (14,600 tn /y)	76,881,380€
Cyclades (Alternative Scenario)	Syros (23,300 tn /y) Naxos (19,400 tn /y)	88,748,710€
Dodecanese (Alternative Scenario)	Rhodes (44,500 tn /y) Kos (21,700 tn/y)	80,055,580€

3.2 The proposed conceptual MSWM model for South Aegean Islands

The existing policy planning focuses on optimal management of MSW at island scale by creating the minimum needed local infrastructures, with the remaining fraction been directed to larger, nearby islands. Even if for very small islands this is the only viable solution, for medium-sized ones (as the majority of islands in the Cyclades complex), flexible sizing and plants diversification that will work on a complementary basis for a set of nearby islands, could be both viable and economic profitable.

Traditionally, nearby small islands, have been resources' efficient as a result of their well-established close-loop commercial connections. This is the underlying idea of the proposed conceptual model for South Aegean islands: to establish waste-stream commercial connections between nearby islands, also taking into account: i) the basic principles of circular economy, ii) the existing Waste Management Regional Plan (PESDA), iii) equal chances for profit for the all the islands, iv) "matching" of local in MSWM infrastructures according to their MSW production activities, v) promotion of sustainable tourism and vi) local business innovation.

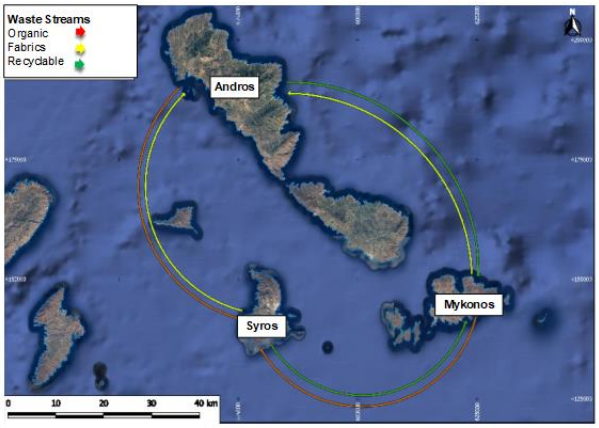

Figure 1. The circular model for Cyclades – Group example

So, three islands from Cyclades are selected to introduce the model idea. The concept is that we can create for a group of (nearby) islands complementary infrastructures that will efficiently manage the MSW fraction produced not only locally but also from the other (two) nearby islands, as considered grouped in the MSW circular model. Each island will host one facility reflecting the activities and related MSW products that are locally dominant and in total the set of (3) plants are meant to cover all aspects and needs of integrated solid waste management; a recycling plant for fabrics (small-scale clothing fabrication is an activity that is still present in many Greek islands), a typical recycle/ sorting plant for paper-glass-etc and a MRF plant (for the organic fraction). It must be noted that the basic infrastructures at island level remain the same (as in PESDA) and only the size and type of MRF units is considered as a variable.

Table 2. Existing waste fractions (in tn/y) for Syros, Mykonos and Andros islands of Cyclades complex (PESDA, 2016)

	Syros (in tn/y)	Mykonos (in tn/y)	Andros (in tn/y)
Total MSW	14,203	19,286	6,805
Recyclable fraction (4% of which are considered to be fabric)	6,117	8,306	2,931
Organics / biowastes	1,758	2,387	842
Other recyclables (i.e. batteries)	572	777	274
MRF fraction	5,756	0	0
Direct landfill no pre-processing	0	6,768	2,388
Landfilled processed residue	2,867	7,816	2,758

So considering the waste fractions of Andros, Syros and Mykonos (Table 2) as well as the existing plan of PESDA the followings are suggested at island level (Table 3):

- Waste transfer stations are planned for all islands (small upgrade in Mykonos) with a variable capacity (8,000-35,000 tn/year)
- Waste transfer stations for recyclables are planned for all islands (small upgrade in Andros) with a capacity (>5,000-tn/year)
- **One main recycling/sorting plant** that will be hosted in Mykonos –receiving the relative fraction from the other two islands at a capacity of approx. 44,500 tn/year (also accounting the touristic infusion)
- **One main MRF plant** of approx. 14,400 (tn/y) in Syros receiving the relative fraction from the other two islands
- **One main fabric recycling facility** in Andros of approx. 905 (tn/y) receiving the relative fraction from the other two islands
- Finally, landfilled fraction accounts for only 25% of the initial quantities and is diverted at a cost of 5€/tn -since it's a process residue- for end disposal (all initial quantities are increased at a scale of 10-times also incorporating the touristic fluctuations).

Table 3. Facilities and investment costs as quoted in PESDA alternative scenario (2016) and authors' proposed amendments appearing in green

	Syros	Mykonos	Andros
Recyclable collection / mixed MSW	129,700 €	53,200 €	182,500 €
Biowaste collection	275,400 €	204,150 €	171,500 €
Green points creation	564,200 €	703,700 €	837,800 €
Household composting	62,000 €	89,900 €	29,800 €
Waste transfer station	690,000 €	620,000 €	320,000 €
		690,000 €	690,000€
Waste transfer station for recyclables	588,000 €	588,000 €	560,000 €
			588,000 €
Recycling/ sorting plant		980,000 €	
Processing of pre-sorted organic fraction /MRF plants	8,897,000 €	620,000 €	272,900 €
	9,789,900 €	0 €	0 €
Final (end) disposal of waste residue	2,244,800 €	0 €	5,879,300 €
	180,000 €	240,000 €	170,000 €
Landfill restoration	2,244,800 €	889,300 €	701,300 €
Total scenario cost	12,173,100 €	3,180,250 €	8,955,100 €
	12,279,200 €	4,438,250 €	3,370,900 €

As one may see, there is a margin for cost savings (17%), a benefit that can increase if also accounting that each island can profit from selling the recovered materials to appropriate markets. Finally, local employment creation should be also considered on the side of benefits of the proposed community based- MSWM solution.

4. Conclusions

Historically, islands owing that to their relatively small population and the respective small amounts of waste generated, were not in line to a particular waste management strategy. However, for the majority of islands around the world, waste management is considered a growing and very serious problem as the range of realistic options for managing waste is inevitably limited, narrowed also by aesthetic limitations. The review of MSWM practices at island level evidenced that the particular characteristics of each island, makes clear that one-size/type-fits-all solution can be used. Also, that there is no integrated MSWM system in the context of circular economy. In Greek islands, MSWM is going through a big transition, provisioning in the coming years a set of infrastructures for each island to cover all waste streams to be managed. However, reaching high recovery and recycling goals, can be incentivized on the basis of creating facilities that fitting the profile of each island and acting synergistically to a material recovery market can safeguard better participation rates in recycling from the local population. Finally, the present work sets the foundations for the development and implementation of an integrated MSWM system based on "circular economy" and "energy community" principles, a model that isolated island groups could benefit from.

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