Department of Waste and Resource Management

Rostock University

SOLID WASTE MANAGEMENT IN TOURISM DESTINATIONS IN TUNISIA: DIAGNOSTIC AND IMPROVEMENT APPROACHES

DISSERTATION

Submitted in fulfilment of the requirements of the

Academic Board of Rostock University

Faculty of Agriculture and Environmental Sciences

For the Degree of DOCTOR of Engineering (Dr. Eng.)

WASSIM CHAABANE

Born in Sfax 1988, Republic of Tunisia

Rostock, Germany

2020

https://doi.org/10.18453/rosdok_id00002705

Gutachter:

1. Gutachter:

   PD. Dr.-Ing. Habil. Abdallah Nassour

   Universität Rostock

   Justus-Von-Liebig-Weg 6, 18059 Rostock, Germany.

2. Gutachter:

   Prof. Dr.-Ing. Christina Dornack

   Institute of Waste Management and Circular Economy - Technische Universität Dresden

   Pratzschwitzer Str. 15, 01796 Pirna, Germany

3. Gutachter:

   Dr. Mehrez Chakchouk

   University of Tunis - Preparatory Institute for Engineering Studies of Tunis (IPEIT)

   2, Rue Jawaher Lel Nehru - 1089 Montfleury - Tunisie

Datum der Einreichung: 06.11.2019

Datum der Verteidigung: 17.04.2020

DECLARATION OF INDEPENDENCY

I hereby declare that the present work is prepared and submitted by me independently without any assistance other than from those cited and acknowledged in the thesis.

Rostock, 06. 11. 2019
Wassim Chaabane

Tunisia has established, since 1993, a national solid waste management (SWM) programme to implement an integrated waste management strategy. The National Waste Management Agency (ANGED) has started with the rehabilitation of open dumpsites, the creation of sanitary landfills and with the treatment of emitted gas and leachate. Laws have also established the conditions and arrangements for the recovery and management of used packaging systems (ECO-Lef), used batteries and accumulators (Eco-batteries), and the arrangements for waste generated from medical activities, etc.

Since the revolution of January 14, 2011 that were accompanied by socio-economic changes, there has been a worrying deterioration in terms of SWM in both urban and rural areas, as evidenced by the proliferation of solid waste dumps and blackheads, as a consequence of the perturbation of most of the waste collection and recycling channels (striking workers, demonstrations, etc.). At the same time, since 2018, Tunisia has started a decentralisation process that aims to give more power to the local authorities, who are considered to be the most important actors in the SWM sector. Currently, municipalities face several difficulties such as the lack of data, the lack of knowledge and the financial insufficiency. The situation is getting more complicated in tourism destinations; the amount of waste generated increases intensively during the summer due to the number of tourists visiting such areas in Tunisia, particularly in the last three years, which has created more pressure for the municipal resources and led to the spread of trash in the destination.

Therefore, a new integrated SWM concept focusing on the whole cycle (waste collection, transfer and transport, treatment and disposal, beaches and roads cleaning, and so on), and supported by a strong legal, organisational and institutional frameworks, is required to ensure clean, circular and sustainable tourism throughout the year.

This thesis aims to diagnose the SWM situation in tourism destinations in Tunisia in order to develop possible organisational, financial and technical improvement solutions; this could be adopted and implemented to guarantee an integrated and sustainable SWM for tourism and, consequently, increasing the satisfaction of local citizens, tourists and visitors, and improving the incomes of the tourism sector.

The work is organised in five parts: **The first part** of the thesis evaluates the present SWM practices in Tunisia. It provides the history and overview of the current situation, as well as some facts and figures related to the sector. In addition, a literature review of the SWM in tourism destinations is presented.

The second part focuses on the development of adequate organisational, financial, technical, legal and social key indicators for SWM in tourism areas; following this is a series of discussions with national and local actors related to the sector. These indicators represent a basis for the data collection at national and local levels (i.e. the case of Hammamet city and Gammarth). It aims to better understand the different aspects of the sector and serves to support the decision-making process. After a detailed analysis of the current concept, its barriers and difficulties, some sustainable and integrated solutions are

developed. A part of this part was carried out with the financial support of GIZ/CoMun project.

The third part of the thesis is the reinforcement of the organisational concept of SWM in the tourism sector based on a participatory approach including all concerned actors, particularly the federation of hotels. The concept is developed after a deep diagnostic of the current organisational situation, as well as several discussions with the national and local actors. The concept should be sustainable and provide more alternatives and solutions for local authorities, particularly reducing the SWM costs.

The fourth part of this thesis analyses the current recovery and recycling system, ECO-Lef, to identify the gaps and to understand the barriers that lead to the decreased collected quantities. In order to identify the existent recyclable fraction, a sorting analyses were performed in four zones in Tunis governorate: Sidi Bousaid, Bardo, Hrairia and Hammamet. For the case of Hammamet city, the sorting was elaborated for waste generated from both hotels and households. Furthermore, several meetings with concerned actors (national and local authorities, producers and fillers, importers of goods, private collection and recycling companies, NGOs) were performed to diagnose the situation and to discuss possible scenarios. This part presents the possibility of optimising the current ECO-Lef system and to develop an extended producer responsibility (EPR) concept adapted to the Tunisian context. This project is carried out with the co-financement of the GIZ and the consortium cyclos/envero GmbH.

The fifth part monitors the composting process of a raw material of source-separated kitchen organic waste and green waste from Gammarth tourism destination in Tunisia. The experiments were conducted to explore the physical and chemical properties of the produced compost. The produced compost was monitored in terms of pH, total organic carbon, total nitrogen, total phosphorus, total potassium, C/N ratio, as well as heavy metal concentrations and compost respiration (AT4). The final product quality was examined and assessed against the quality specifications of the German End of Waste Criteria for bio-waste (BioAbfV) and Tunisian compost standards (NT 10.44 -2013). This project was implemented in cooperation with the municipality of La Marsa, with the support of the international centre of environmental technologies (CITET) and the University of Rostock.

In conclusion, the findings indicate that decision-makers at national and local levels lack data related to SWM in tourism areas. The developed key indicators were an asset to diagnose the situation and to develop suitable solutions to improve the SWM sector and to ensure clean tourism destinations. In terms of organisational solutions, the developed solutions shows that the concept should be based on a participatory approach involving all concerned actors. In addition, results show that the development of an EPR system needs a good understanding of the national framework, which must be developed through consultation with all national and local actors, and public and private sectors, concerned with the system. A new system operator (NOS), being a not-for-profit organisation, is to be created in Tunisia to manage the system organisationally and financially. The system should be controlled by ANGED, which should also develop the collection and recycling targets with the concerned actors. Furthermore, and since organic fraction and green waste represents a big challenge for tourism destinations, the composting of clean

products could be an important solution to avoid a problem, to reduce waste that is landfilled, and to create new opportunities from the product, which could be used for private, public and agricultural activities.

All these solutions should be supported by other actions such as raising the consciousness of citizens and tourists about this issue and the education of the decision makers of both public and private sectors.

ZUSAMMENFASSUNG

Tunesien hat 1993 ein nationales Abfallwirtschaftsmanagementsystem (SWM) zur Umsetzung einer integrierten Abfallwirtschaftsstrategie eingeführt. Die National Waste Management Agency (ANGED) hat mit der Sanierung von unkontrollierten Ablagerungen, der Errichtung von Standarddeponien und der Behandlung von Deponiegasen und Sickerwässern begonnen. Die Gesetze und auch die Bedingungen und Maßnahmen wurden für die Rückgewinnung und das Management von gebrauchten Verpackungssystemen (ECO-Lef), gebrauchten Batterien und Akkumulatoren (Eco-Batterien) und Abfälle aus medizinischen Tätigkeiten usw. entwickelt.

Seit der Revolution vom 14. Januar 2011 und die dadurch bedingten sozioökonomischen Veränderungen ist sowohl in städtischen als auch in ländlichen Gebieten eine besorgniserregende Verschlechterung der SWM sowie eine Störung der meisten Abfallsammel- und Recyclingkanäle (Streikende, Demonstrationen usw.) zu verzeichnen. Seit 2018 hat Tunesien einen Dezentralisierungsprozess eingeleitet, welcher den lokalen Gebietskörperschaften mehr Macht im SWM-Sektor zugesteht. Derzeit stehen die Kommunen vor mehreren Schwierigkeiten, wie Mangel an Daten, fehlendes Know-how, sowie die Gewährleistung einer nachhaltigen Finanzierung. Speziell in Urlaubsregionen wird die Situation immer komplizierter. Die Abfallmenge steigt in der Hochsaison im Sommer aufgrund der hohen Anzahl an Touristen. Dies erhöht den Druck auf die kommunalen Ressourcen und führt zu einem erhöhten Abfallaufkommen in diesen Orten.

Daher ist ein neues integriertes ganzheitliches SWM-Konzept (Abfallsammlung, -transport, -behandlung und -entsorgung, Reinigung von Stränden und Straßen usw.) erforderlich. Die Basis dazu sind angepasste gesetzliche, organisatorische und institutionelle Rahmenbedingungen, um nachhaltigen Tourismus für das gesamte Jahr zu gewährleisten.

Ziel dieser Arbeit ist es, die SWM-Situation in tunesischen Urlaubsregionen zu untersuchen, um mögliche organisatorische, finanzielle und technische Verbesserungslösungen zu entwickeln. Diese können übernommen und umgesetzt werden, um eine integrierte und nachhaltige SWM für den Tourismus zu gewährleisten und folglich die Zufriedenheit der Bürger, Touristen und Besucher vor Ort zu erhöhen und den Umsatz des Tourismussektors zu steigern.

Die Arbeit gliedert sich in fünf Teile: **Der erste Teil** bewertet den gegenwärtigen Stand der Abfallwirtschaft in Tunesien. Es umfasst die Geschichte und den Überblick über die aktuelle Situation sowie einige Fakten und Zahlen. Zusätzlich wird eine Literaturübersicht der SWM in Urlaubsregionen vorgestellt.

Der zweite Teil befasst sich mit der Entwicklung angemessener organisatorischer, finanzieller, technischer, rechtlicher und sozialer Schlüsselindikatoren für Abfallwirtschaft im Tourismussektor. Außerdem werden die Ergebnisse einer Diskussion

mit nationalen und lokalen Akteuren der Branche zusammengefasst. Die oben genannten Indikatoren bilden die Grundlage für die Datenerhebung auf nationaler und lokaler Ebene. Das Ziel ist es, die verschiedenen Aspekte des Sektors besser zu verstehen und den Entscheidungsprozess zu unterstützen. Nach einer detaillierten Analyse des aktuellen Konzepts, seiner Hindernisse und Schwierigkeiten werden einige nachhaltige und integrierte Lösungen vorgeschlagen. Teil der Untersuchungen wurde mit finanzieller Unterstützung des Projekts GIZ / Commun durchgeführt.

Der dritte Teil der Arbeit befasst sich mit der Stärkung des Organisationskonzepts der Abfallwirtschaft im Tourismussektor unter Einbeziehung aller betroffener Akteure, insbesondere des Hotelverbands. Das Konzept wurde auf Grundlage der eingehenden Auswertung der aktuellen organisatorischen Situation sowie mehreren Gesprächen mit den nationalen und lokalen Akteuren entwickelt. Das Konzept soll nachhaltig sein und den lokalen Behörden mehr Alternativen und Lösungen bieten, insbesondere zur Sicherung der notwendigen Kosten.

Der vierte Teil dieser Arbeit analysiert das derzeitige Verwertung- und Recyclingsystem ECO-Lef, um mögliche Schwachstellen und die Hindernisse für die Senkung der gesammelten Mengen zu identifizieren. Um die vorhandene recycelbare Fraktion zu analysieren, wurden in vier Zonen des Gouvernements Tunis Sortieranalysen durchgeführt: Sidi Bousaid, Bardo, Hrairia und Hammamet. Darüber hinaus wurden mehrere Workshops und Diskussionen mit betroffenen Akteuren (nationale und lokale Behörden, Hersteller und Abfüller, Importeure von Waren, private Sammel- und Recyclingunternehmen, NRO) durchgeführt, um die derzeitige Situation zu erfassen und mögliche Lösungsansätze zu erörtern. Im Rahmen dieses Kapitels wurden Lösungsansätze für die Optimierung des ECO-Lef-Systems für eine erweiterte Herstellerverantwortung (EPR) erarbeitet. Dieses Projekt wird unter Mitfinanzierung der GIZ und des Konsortiums cyclos / envero GmbH durchgeführt.

Der fünfte Teil befasst sich mit dem Kompostierungsprozess der organischen Küchenabfälle und des Grünschnitts aus der touristischen Region Gammarth in Tunesien. Die Versuche wurden durchgeführt, um die physikalischen und chemischen Eigenschaften des hergestellten Komposts zu untersuchen. Der produzierte Kompost wurde hinsichtlich des pH-Werts, des gesamten organischen Kohlenstoffs, des gesamten Stickstoffs, des gesamten Phosphors, des gesamten Kaliums, des C/N-Verhältnisses sowie der Schwermetallkonzentrationen und der Kompostatmung (AT4) untersucht. Die Produktqualität wurde geprüft und mit den Qualitätsspezifikationen der deutschen Bioabfallverordnung (BioAbfV) und der tunesischen Kompostnormen (NT 10.44 -2013) verglichen. Dieses Teilprojekt wurde in Zusammenarbeit mit der Gemeinde La Marsa mit Unterstützung des Internationalen Zentrums für Umwelttechnologien (CITET) und der Universität Rostock durchgeführt.

Zusammenfassend lässt sich feststellen, dass den Entscheidungsträgern auf nationaler und lokaler Ebene die Ist-Daten zur Abfallwirtschaft in Tourismusgebieten fehlen. Die entwickelten Schlüsselindikatoren sind von Vorteil, um die Situation zu quantifizieren

und geeignete Lösungen zu entwickeln, um die Abfallwirtschaftssituation zu verbessern und saubere Urlaubsregionen zu gewährleisten. In Bezug auf organisatorische Lösungen zeigen die entwickelten Lösungen, dass das Konzept auf einem partizipierenden Ansatz basieren sollte, an dem alle betroffenen Akteure beteiligt sind. Darüber hinaus zeigen die Ergebnisse, dass die Entwicklung eines EPR-Systems ein gutes Verständnis des nationalen Rahmens und das Zusammenwirken aller nationalen und lokalen Akteure erfordert. In Tunesien soll ein neuer Systembetreiber (NOS) als gemeinnützige Organisation geschaffen werden, der das System organisatorisch und finanziell verwaltet. Das System sollte von ANGED kontrolliert werden. Ferner sollten sie auch die Sammel- und Recyclingziele mit den betroffenen Akteuren ausarbeiten. Da organische Fraktionen und Grünabfälle eine große Herausforderung für die Urlaubsregionen darstellen, könnte die Kompostierung eine gute Lösung sein. Dadurch wird die Menge der deponierten Abfälle reduziert.

Alle diese Lösungen sollten durch weitere Maßnahmen wie die Öffentlichkeitsarbeit für die Bürger und Touristen sowie Sensibilisierung der Entscheidungsträger des öffentlichen und des privaten Sektors unterstützt werden.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACR+: International Network of Cities and Regions

ANGED: National Waste Management Agency

ANPE: Agency of Environmental Protection

APAL: Coastal Protection and Development Agency

CITET: International Centre of Environmental Technologies of Tunis

DSD: Duales System Deutschland

Eco-batteries: National System of Batteries Recovery

ECO-Lef: Recovery of Packaging Material System

Eco-piles: National System of Small Batteries Recovery

Eco-pneus: National System of Recovery of Used Tires

Eco-zit: National system of recovery and regeneration of used lubricating oils

EPR: Extended Producer Responsibility

FODEP: Depollution Fund

FTAV: Federation of Travel Agencies

FTH: Tunisian Federation of Hotels

GHG: Greenhouses Gas

IRST: Reception, Storage and Transfer Facilities (Hazardous waste)

MBT: Mechanical Biological Treatment

MLAE: Ministry of Local Affairs and Environment (Tunisia)

MSW: Municipal Solid Waste

MSWM: Municipal Solid Waste Management

NGO: Non-Governmental Organisation

NOS: New System Operator (Nouveau Opérateur du Système)

OECD: Organisation for Economic Co-operation and Development

PCGD: Communal Plan of Waste Management (Plan Communal de Gestion des Déchets)

PRO: Producer Responsibility Organisation

SWM: Solid Waste Management

TND: Tunisian Dinars

UNWTO: United Nations - World Tourism Organization

1. INTRODUCTION AND PROBLEM STATEMENT

The rapid development of the tourism industry has had a direct impact on the increase of the amount of solid waste in tourism areas. This has had a negative impact on the environment (Giurea et al., 2018), namely higher operational costs, blight owing to litter and contaminated water, and a reduction in the touristic value of otherwise attractive locations (Edmundo et al., 2015). Improper management of municipal solid waste (MSW) can cause serious damage to ecosystems by increasing water, soil and air pollution (Makule, 2000; Sastre, 2015). Furthermore, it may also increase the possibility of serious impacts on public health and human safety (Pervez et al., 2013; Lisa et al., 2003).

The environmental impacts of MSW generation have increased pressure on public authorities to develop policy options and new concepts to deal with this issue (Magrinho et al., 2006; Rotich, 2006; Manga, 2008; Shekdar, 2009). Specific concepts could be interesting for the case of tourism destinations since tourism inflows constitute another source of MSW, and the attractiveness of these areas can be affected (Mathieson, 1982; Gidarakos, 2006; Radwan, 2010).

Therefore, an increase in the number of tourists increases the quantity of waste generated, which makes the operation even more complicated. It should be noted that quantities of waste generated by tourism establishments are large in absolute terms – 35 million tons per year globally (Gutierrez et al, 2005), and that a tourist may generate up to twice as much solid waste per capita as local residents (IFC, 2007).

Solid waste management (SWM) concepts in tourism destinations have their own rules; it concerns not only waste collection from households and hotels, but also beaches and streets cleaning, developing good infrastructure, communication about responsibilities and public services, and so on. In addition, the cleanliness of coastal tourism areas is considered to be the main indicator of the coastal quality. However, coastal regions are susceptible to litter accumulation, and marine litter has become a global issue (Liu et al., 2013). Indeed, the collection of relevant, credible and informative data remains an important step to developing a good integrated strategy for SWM.

Enough data of sufficient quality will need to be collected for reliable decision-making and evaluation. Good and effective SWM strategies require knowledge of who generates the waste and what types of waste are generated, not just the volumes that are produced. All SWM strategies developed without quality data are not likely to optimise decision making and might, in some cases, result in inaccurate decisions.

Tunisia is a small country on the North African coast with a 1300 km-long coastline; it holds a central position in the Mediterranean Sea and has a very important mass tourism activity, which represents a major source of environmental pressure on the natural resources and coastal areas including water and waste pollution (Switchmed.eu, 2017). In Tunisia, tourism is an industry that has seen continuous development, and reached eight million tourists in 2018, according to the Tunisian Ministry of Tourism. Such an

evolution must be associated with good organisation and management of the large amounts of solid waste generated. For instance, according to the Ministry of Local Affairs and Environment (MLAE), Djerba island where hotels generate 45% of the total waste, has been experiencing a major SWM crisis since 2012, which exists today. The government is aware that this crisis must not be duplicated in other tourist areas in the country (Kapitalis, 2018).

Currently, tourism destinations in Tunisia are facing several SWM challenges. The economic crises and the lack of financial means and expertise, the lack of organisation between the different stakeholders at national and local levels, as well as technical and communication issues, represent the main barriers facing local authorities and actors.

Technical barriers are principally related to the lack of collection points for local residents, visitors and tourists, the irregularity of waste collection caused by logistical or social problems, inadequate waste collection vehicles, inadequate access to waste bins as well as the absence of treatment infrastructure in some areas. Furthermore, the lack of local know-how and of skilled manpower represent a crucial barrier facing the improvement of the sector. In addition, the informal sector dominates the packaging recovery system ECO-Lef. Moreover, barriers to proper SWM are principally related to space problems, since all landfills in Tunisia are actually at their end of life.

Financially, the main problem is linked to the inadequacy of these resources and funding; the cost recovery from the population for waste management services do not exceed 27%. Further, municipalities waste collection expenses can reach more than 50% of the municipality budget. In addition, in most cases the fees go to a central treasury or to central funds, and are distributed without clear criteria. In contrast, tourism municipalities need large financial means to perform SWM activities properly. Further, several waste materials has no value and could not be collected by the informal sector or by the official system, which makes its collection and recycling difficult and it ends up on the beach, in the sea and nature.

Moreover, organisational and management barriers are connected to the lack of planning and strategies, inadequate policies and weak legislation, as well as the lack of partnership and cooperation between all concerned actors in tourism areas. Further, the framework is characterized by an unclear responsibilities and the overlap of powers.

Other communication problems also exist, such as the lack of information and data, and inappropriate and unsustainable communication programmes. In addition, socio-cultural obstacles are linked to the paucity of participation and engagement in waste management projects, the lack of engagement of local enterprises and NGOs, and the aggravation of the negative attitudes related to SWM.

After the municipal elections of May 2018, which intended to decentralise decision making, municipalities in Tunisia have more power and financial independence to take decisions in the framework of a democratic process.

The general objectives of this thesis are:

- To improve understanding of the current SWM situation in Tunisia at the national and local levels, particularly in tourist destinations;
- To collect and analyse data about international experiences related to SWM in tourism destinations (e.g., organisation, financial, legal framework, etc.);
- To develop a core set of indicators and to provide an analysis of the SWM in tourism areas in Tunisia, targeting technical, legal, financial, organisational and social aspects;
- To analyse the current organisational concept and to develop sustainable solutions;
- To carry out diagnostics of the packaging recovery and recycling system in Tunisia (ECO-Lef) and the development of an Extended Producer Responsibility (EPR) concept to increase packaging collection and recycling rates of packaging and to improve the cleanliness of tourism areas;
- Monitoring of the composting process made from different source-separated kitchen organic waste and green waste raw materials generated from Gammarth tourism destination;

2. REVIEW OF SOLID WASTE MANAGEMENT SECTOR IN TUNISIA

The SWM sector in developing countries is characterised, despite addressing the same issues as in industrialised countries, by various implementation methods, which depend on the local socio-economic realities (Günay, 2000). In general, local authorities are in charge of the solid waste collection and transportation. However, they generally lack the institutional, human, technical and financial means to ensure its convenient functioning. In addition, the centralisation or the incomplete implementation of the decentralisation processes make them highly dependent on state transfers, which are often inadequate or inefficient.

This chapter presents an overview of the SWM system in Tunisia, including the legal, institutional and financial frameworks, highlighting the existing collection and recovery of recyclables system. Collected data was based on several research trips, interviews and visits with responsible persons in the national and local authorities (MLAE, the National Waste Management Agency [ANGED], municipalities, etc.), the private sector (collection and recycling companies, waste management treatment operators), non-governmental organisations (local NGOs, federation of NGOs, etc.), and the informal sector (waste pickers named 'Barbechas', informal waste collection and recycling companies).

2.1. OVERVIEW OF SOLID WASTE PRACTICES IN TUNISIA

Given its geographical location, Tunisia is a country located in MENA region, where solid waste management is considered as one of the major challenges (Nassour et al., 2018). The growing population and rapid urbanisation generates large amounts of solid waste. However, the infrastructure is not adequate to deal with the problem. In addition, local governments in developing nations are not able to provide this important public service accurately (Medina, 2002). The municipalities have generally assumed the responsibility for the collection, transfer and disposal of the generated waste (Zerboc, 2003).

In Tunisia, as many countries in the Arab region, up to 50% of the generated waste goes uncollected, the waste that is collected is mainly mixed (Naas, 2015) and only a few and small sorting and recycling initiatives exist. The typical method of municipal waste disposal is dumping; it is poorly managed and lacks most of the basic engineering and sanitary measures for the collection and treatment of gas and leachate (Nassour et al., 2011). The inability of the existing SWM systems to manage the growing waste generation rates has led to significant health and environmental problems in most Arab countries (Abaza et al., 2011).

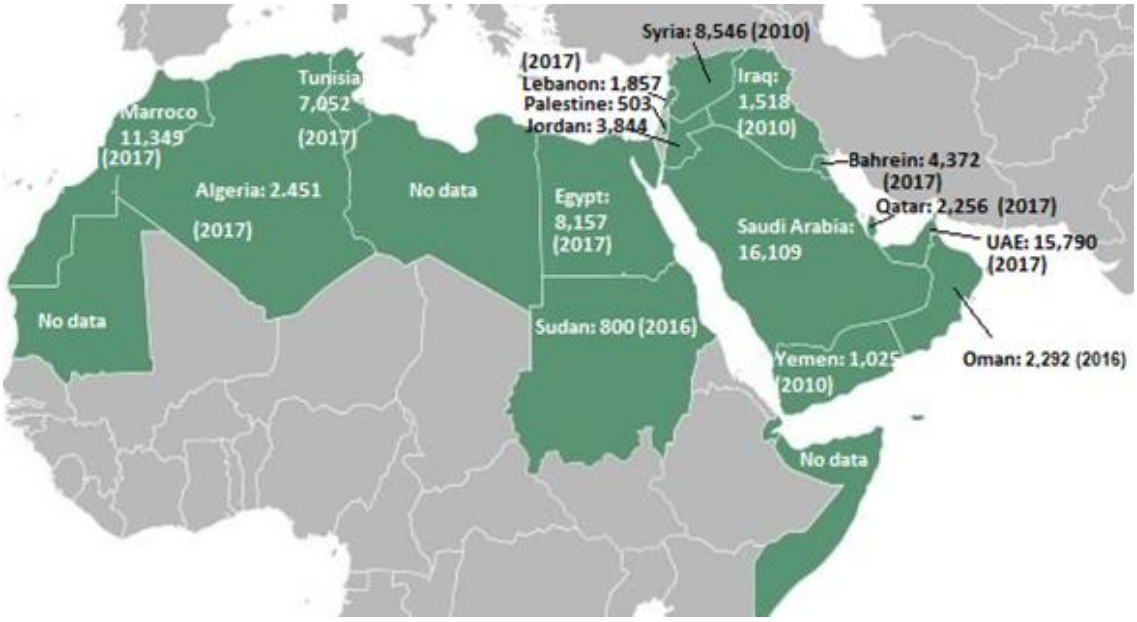

Figure 2-1. *International tourist arrivals in MENA countries in 2010, 2016 and 2017 (UNWTO, 2018)*

Indeed, tourism destinations in Tunisia and in the region generate large amounts of waste. However, little research has been published on the SWM sector in these areas. There has recently been a growing and popular interest in tourism activities within the Arab world (Figure 2-1), which includes countries in the MENA region (Jafari, 2014).

2.2. OVERVIEW ON THE ENVIRONMENTAL SECTOR IN TUNISIA

Tunisia is located in the Maghreb region of the MENA region, covering 163,610 km^2, with a population of 11.435 million in 2017. In 2010, Tunisia was the world's fifth producer of phosphate and in Africa it was the second leading phosphate producer. Other than phosphate, the country also produces cement, aluminium fluoride, refined petroleum products, gypsum, crude oil and common clay (Azomining, 2012).

The Tunisian culture links the environmental questions principally to the cleanliness and to the quality of the provided SWM services, particularly waste collection. This question concerns Tunisian citizens in their daily life. It concerns also the tourism sector, as a main generator of jobs position and national income. Many other environmental problems are in question in Tunisia, and are related to the deterioration and lack of water resources, air pollution, soil degradation, degradation of the coastal areas, and loss of biodiversity, which have all been associated in various levels to climate change.

Since the revolution, Tunisia has faced a critical economic and political crisis. In parallel, and over eight years, there has been a worrying degradation in SWM, both in urban and rural areas, which manifests itself in the proliferation of solid waste, landfills and black spots. Several events took place against the degradation of the environmental situation, and against the landfilling in some regions, such as Djerba, Kerkennah, etc. The causes are multiple and are on several levels; for instance, the dissolution of municipal councils and their replacement by special delegations, the dissolution of rural councils for

collecting and transporting waste, significant damage to municipal premises as a result of social demands, repetitive strikes by municipal workers demanding improvements in working conditions, closure of landfills and transfer centre facilities by the neighbour population, a difficult financial situation and the total absence of citizens' behaviour characterised by the absence of eco-citizenship.

Formally, the constitution of 2014 included articles referring to environmental protection and the promotion of sustainable development. However, at an institutional level, in 2014, the Ministry of the Environment was merged with the Ministry of Equipment of the Amendment of Territory and Sustainable Development, which does not change a lot of things; this situation gave rise to further environmental protests (Loschi, 2019).

The SWM and cleanliness sectors were classified as a fifth priority of the government of 2016. The government chose to combine the Ministry of the Environment with the Ministry of Local Affairs to support the SWM process through the enforcement of local authorities during the decentralisation process.

2.3. CURRENT SWM SITUATION IN TUNISIA

In Tunisia, the SWM sector has been recognised as a vital policy area in general efforts towards the improvement of living conditions. One of the most visible effects of the 2011 uprising in Tunisia were mountains of uncollected garbage, not only in lower income neighbourhoods, but also in well-off districts and cities throughout the country. The scenario became all too familiar to both citizens and tourists visiting the country on holiday (Loschi, 2019). In Tunisia, the urbanisation development and the growth rate of the population are the main reasons for the SWM crisis, which increases during the year and particularly during the summer period.

In the last three years, Tunisia has realised that the SWM situation does not satisfy the sustainable development goals and decided to shift toward establishing integrated SWM approaches. Despite the efforts of the authorities, SWM still faces many challenges in Tunisia such as the lack of legislation, lack of financing, lack of human resources and experience, inappropriate technologies, lack of availability of primary data on per capita waste generation, inadequate data on waste characteristics, the influence of the informal sector, different reports giving different values and projections, the lack of good governance and civil society's inactivity, which are the common problems with regard to SWM facing the decision makers. It can be observed that several improvements still need to be targeted in terms of policy, strategy, institutional set-up, legal framework, involvement of the private sector and capacity building. Indeed, there is a need for immediate action to establish an integrated system for SWM in Tunisia.

Today, the country produces more than 2.8 million tons of solid waste (MLAE, 2017) in comparison to 1.8 million (in 2002), with an increasing rate of 2.8% per year. According to the MLAE, about 80% of the generated waste is appropriately disposed of, while about 20% ends up in inappropriate areas. According to the results published by the World Wildlife Fund – WWF (2019), Tunisia generated 0.25 million tons (Mt) of plastic waste

in 2016, of which 0.05 Mt (20%) remained uncollected and 0.20 Mt (80%) was collected for waste treatment. A total of 0.15 Mt (60%) of this waste was sent to landfills, 0.04 Mt (16%) was openly disposed of in the wild, and only 0.01 Mt (4%) was recycled. In 2016, it was determined that 8.5 kT of plastic waste was discharged each year into the Mediterranean Sea. The Tunisian economy loses about $20 million (USD) a year due to plastic pollution affecting tourism, shipping and fishing sectors

2.3.1. Waste Composition

A large difference exists worldwide between MSW generated in developed and developing countries in terms of waste composition. Municipal solid waste generated in developed countries is mainly inorganic in nature, whereas organic content dominates the waste in developing countries (Zerboc, 2003; Zurbrugg 2003). The proportion of organic content in developing countries is almost three times higher than that in developed countries, followed by recyclable materials, mainly plastics and paper (Al-Jarallah et al., 2014). Even though the volume of waste generated in developing countries is much lower, compared to that in developed countries, the nature of waste is denser and has a very high humidity content (Al-Jarallah et al, 2014; Zurbrugg, 2003).

The lifestyle, current activities in a region, geographical and climatic conditions and population influence the nature and the composition of waste (Abu-Salah et al., 2013). Being vastly organic and humid in nature, waste in developing countries presents both opportunities and restraint that are entirely different to those faced by developed countries (Zurbrugg, 2003). As reported by ANGED (2018), the composition of household solid waste generated in Tunisia is characterised by the domination of the organic fraction (63.2%), followed by plastic (9.4%), textiles (8.7%), paper and cardboard (8.6%), metal (1.6%), glass (1.1%) and (7.4) for other materials (Figure 2-2).

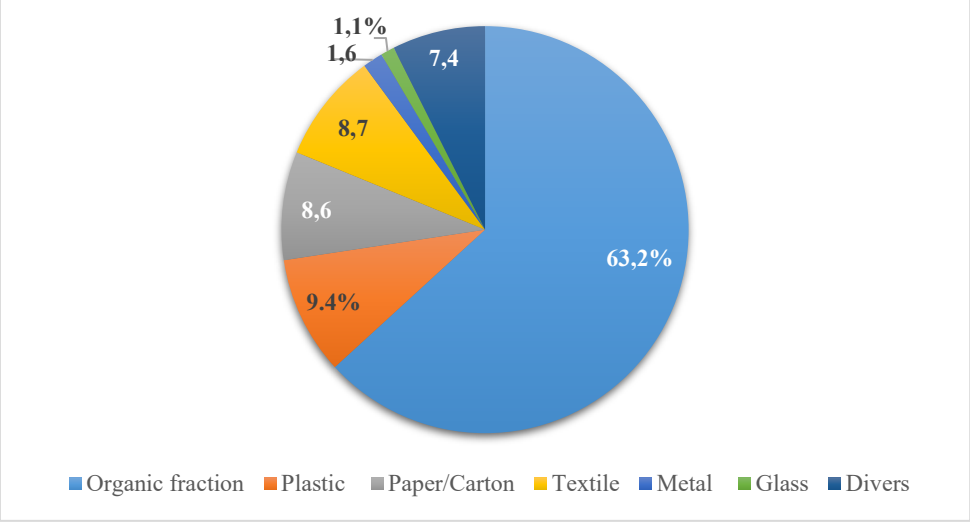

Figure 2-2. *Solid waste characteristics (ANGED, 2018)*

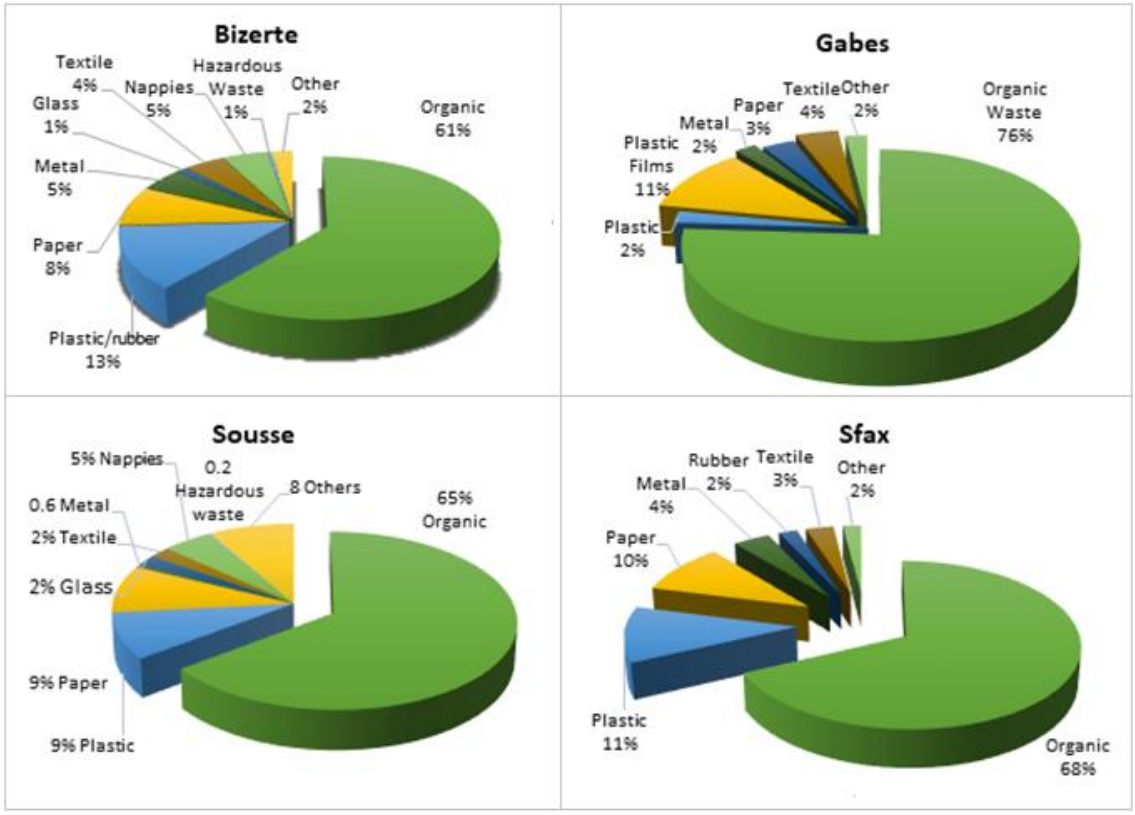

Figure 2-3. *Households' solid waste composition in Bizerte, Gabes, Sousse and Sfax*

In fact, the percentages of the different fractions differ slightly from one city to another. The composition of the solid waste in some cities (Bizerte, Sousse, Sfax and Gabes) are presented in Figure 2-3.

There are various factors influencing MSW composition from one city to another such as the geographical and climatic conditions, population growth, economic income levels and socio-cultural properties. Among them, household income represents an important factor and it affects the waste generation.

2.3.2. WASTE QUANTITIES

Solid waste generation varies as a function of affluence, however, regional and national variations can be significant, as can generation rates within the same city. Table 2-1 represents the different amounts of MSW generated in different governorates in Tunisia (ANGED, 2018):

Table 2-1. *Amounts of solid waste generated in different governorates in Tunisia.*

Regions /governorates	Waste generation (tons/year)
Ariana/Manouba*	400,000
Tunis/Ben Aous*	400,000
Monastir/Mahdia*	260,000
Nabeul/Zaghouan*	240,000

Sfax	230,000
Sousse	200,000
Bizerte	140,000
Beja/Jendouba*	140,000
Medenine/Tataouine*	110,000
Kairouan	110,000
Siliana/Le Kef*	100,000
Gabes	95,000
Kasserine	90,000
Gafsa	90,000
Sidi Bouzid	80,000
Kebili/Tozeur*	70,000
Djerba	70,000
Total	**2.825,000**

*Two governorates

These data were collected from private companies contracted by ANGED and operating in landfills and transfer stations around the country. The quantities of waste generated in cities and areas, where landfills are closed, were estimated by the local authorities.

2.3.3. SWM INFRASTRUCTURE

At the moment, ten landfills in Tunisia and 56 transfer stations are actually in operation. However, three landfills (Monastir, Kerkennah and Djerba) and six transfer stations were closed at the time of this research due to social manifestations and real estate problems. All the landfills and transfer stations were constructed by ANGED and operated by private companies. The construction of these infrastructures led to the closure of uncontrolled dumpsites following the government's National Waste Management Strategy 2010 – 2016. Tunisia has since successfully moved from waste dumping (only three open dumpsites exist in Tunisia) to create more sanitary landfills with methane collection and leachate treatment. The system, however, needs greater efforts to achieve a more effective performance.

Table 2-2. *Existing landfills and operation period.*

Landfill / Period	Borj Chekir	Nabeul	Bizerte	Sousse	Gabes	Kairouan	Sfax	Mednine	Zaghouan	Touzeur
Start date of operation	1999	2009	2007	2008	2007	2008	2008	2008	2018	2017
Planned closure*	2020	2020	2020	2020	2022	2019	2021	2019	2022	2022

*Estimated date of filling including extension

As indicated in the Table 2-2, all existing landfills are almost full despite the extension operations. In fact, ANGED is planning to establish an extension study, taking into

consideration the rehabilitation of the existing locations. Furthermore, two treatment centres for industrial and special waste (IRST Sfax and IRST Gabes) and one treatment centre are all currently closed (Jrado) because of social unrest again the project.

2.3.4. LEGAL FRAMEWORK

Solid waste management has always been one of the strategic pillars of the policy of different governments in Tunisia. The future orientation is to improve and to actualise the framework and to protect the environment. Legally, this policy has led to a variety of regulations developed since 1975; this includes particularly:

- Law 1996-1941, dated 10/06/1996, on the control of the waste management and disposal;
- Law 92 – 122 establishing a depollution fund (FODEP);
- Law 1975-33, dated 14/05/1975, on the organic law of Commons entrusting waste collection in communal areas to municipalities;
- Law n°97-11, of 3 February 1997, promulgating the code of local taxation;
- Decree N° 2317-2005, of 22/8/2005, establishing a national waste management agency (ANGED);
- Decree 726-1989, dated 10/6/1989, relating to rural councils entrusting waste disposal in rural areas to elected councils.

It is to be noted that chapter 12 of Law No. 41, of 10 June, 1996, concerning waste and the control of its disposal and removal, indicates that:

> *The professionals must undertake, on their own initiative or at the initiative of the competent authorities, to establish systems for the recovery of waste and re-packaging and for their re-use and valorisation. Producers and suppliers shall be required to engage in any system to collect, transfer or to valorise certain types of waste and canning waste. The competent authorities may impose the delivery of such wastes or any other wastes to the institutions or interests that they designate and according to the conditions that they specify.*

In addition, chapter nine of Law No. 41 of 10 June, 1996, emphasises that:

> *The producer, promoter or carrier shall be responsible for the recovery of wastes produced by the materials or products that they produce or market. The competent authorities may require them to remove such wastes and, where appropriate, to contribute to recovery and removal systems from other similar or similar products.*

Furthermore, the principle of decentralisation has been confirmed in the recently adopted new “Local Government Code”; this allows local authorities to manage their affairs independently. The entire Tunisian territory, as well as the rural areas, are currently covered by the municipal service, especially the waste collection service. Regarding the decentralisation of the decision, the article 131 of the Tunisian constitution (January 2014) of chapter VII on local authorities stipulates that, “The local community must be based on decentralization, made up of local groups made up of municipalities, destinations and territories covering the whole territory of the Republic”.

In addition, in order to reduce pollution caused by the plastic, the country is actually developing a new law for the prohibition of plastic bags at supermarkets and, in a later step, the prohibition of plastic bags in small shops and kiosks, and the total prohibition of the production and import of plastic bags with a thickness of less than 50 micrometres.

2.3.5. FINANCIAL FRAMEWORK

The central government in Tunisia participates in SWM financing through the development of the infrastructure, via ANGED, and through subsidies and grants. Recurrent costs such as maintenance and private sector contracts are covered by municipalities.

Furthermore, municipalities finance the collection and transportation of waste to transfer stations and landfills. Municipal resources are collected through local taxes, where the recovery rate represents only 27% (according to the MLAE and the Ministry of Finance). Furthermore, in some cases, the fees go to a central treasury and are distributed with unclear criteria. The funding system for waste management is mainly characterised by the absence of financial incentives and effective cost recovery mechanisms. The collection and the transportation are financed through the municipalities' own resources, with the additional contribution of the government.

In addition, in order to manage the ECO-Lef system, ANGED is financed by the Ministry of Finance (through an eco-tax) and by the producers of goods in the country through voluntary contributions.

2.4. INSTITUTIONAL FRAMEWORK AND RESPONSIBILITIES

The existing SWM institutional framework in Tunisia is under revision and development.

Table 2-3. *Institutions and responsibilities in the SWM sector.*

Institutions	Tasks/responsibilities
Nationally	
MLAE	- Preparation and leadership of the national policy on environmental protection - Development of regulations related to environmental protection - Support of the local authority during the decentralisation process (before and after the election of May 2018) - Supervision authority over municipalities and regional councils
ANGED	- Participation in the development of the national SWM programmes - Implementation of projects and investments in the field on the account of the State - Infrastructure operations, transfer facilities and landfills for non-hazardous waste - Hazardous waste treatment infrastructure - Technical assistance to municipalities for SWM

	- Share awareness with waste producers
National Agency for Environmental Protection (ANPE)	- Control and enforcement of the regulations on SWM
Ministry of Finance	- Participation in the development and implementation of financial instruments for SWM and recovery of related taxes
Ministry of Public Health	- Participates in the development and conduct of SWM programmes related to the health sector
Ministry of Industry	- Participates in the development and implementation of programmes related to waste streams from industrial activities - Assigns operating permits for installations classified unhealthy and uncomfortable
Ministry of Trade	- Participates in the development and conduct of programmes related to waste streams from commercial activities
Ministry of Agriculture	- Participates in the development of regulations to protect the environment against pollution caused by SWM operation - Encourages composting initiatives
Locally	
Municipalities	- Collection and transportation of municipal waste to transfer stations - Legal framework at local levels - Infrastructure for waste collection, sorting, composting. - Awareness programs
Environmental Police	- Control and enforcement of SWM laws

Actually, both public bodies (at national and local levels) and the private sector are concerned by the SWM and several organisations and institutions are involved in the process. The key officials of SWM in Tunisia are:

- At the national level: MLAE and ANGED;
- At the local level: municipalities under the organic law and Law N° 96- 41 relating to waste and control of their management and disposal;
- Producers and importers of packaging (future waste): under the framework of Law N° 96-41 (Polluter Pays and Producer-Recuperator Principles) and represented by the different waste recuperation systems such as Eco-pneus, Eco-zit, Eco-Lef, Eco-piles, Eco-batteries, etc.

The SWM system also indirectly concerns, to a lesser degree, other authorities such as the Ministry of Industry and the Ministry of Finance. Table 2-3 presents the roles of the different institutions and actors in the sector in Tunisia.

Municipalities in Tunisia have the main responsibility for SWM operations (collection, streets and beach cleaning, and so on) in the territory. They are responsible for the collection and the transport of the collected mixed waste to the transfer stations.

Figure 2-4 represents a general vision of the SWM institutional framework in Tunisia, including the main actors on the central administration and local levels.

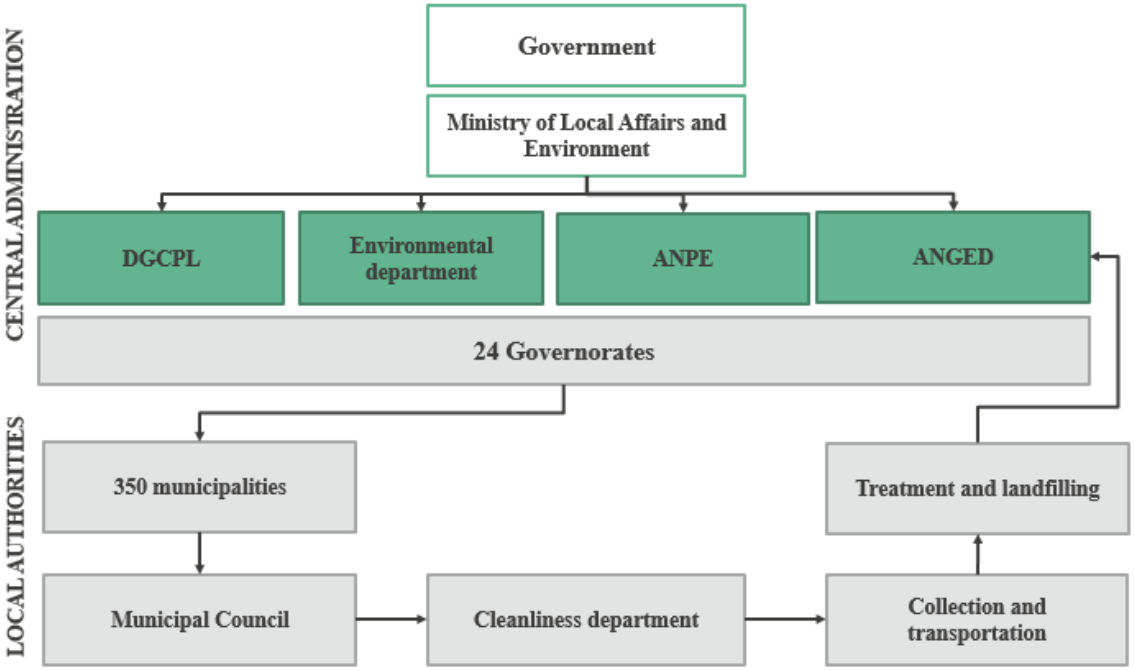

Figure 2-4. *Institutional framework and responsibilities of SWM in Tunisia*

ANGED is in charge of the transport of the waste from the transfer station to the landfill, the role of waste and leachate treatment, and the degasification of the landfills. It is also responsible for providing the adequate infrastructure (transfer stations, landfills or other treatment facilities).

However, the participation of the private sector (particularly in collection and cleaning) is more important in tourism cities; this is particularly so during summer periods where waste generation reaches very high levels.

2.4.1. Role of The Decision Decentralisation in The SWM in Tunisia

Decentralisation is a measure by which responsibility for some function are relocated from the central government to local actors (municipality, civil society, private sector). This process gives greater power in policymaking and decision making to local offices of central government or local private and civil organisations (communities, NGOs, etc.).

In Tunisia, after the extension of the number of municipalities from 265 to 350, the municipal services cover, henceforth, all the Tunisian territory. The municipal elections of May 2018, which represented the country's first-ever democratic local elections, constituted an important step for the consolidation of its democratic transition.

These elections represented only little piece of a much larger decentralisation programme. It should be supported by a strong legal framework for decentralisation, through a clear definition of power and responsibility between the national and local levels. The process also requires the political will to implement decentralisation at both the national and local levels.

Many reasons could justify the decentralisation of decision making related to SWM issues in Tunisia:

- Local institutions, people and private companies have a better knowledge of the environmental, socio-economic and waste management problems of the area and are best placed to find sustainable solutions;
- Local actors have greater motivation to ensure a cleanliness of their city;
- The process involves less favoured groups and populations in the decision making;
- It facilitates local participation and ensures a higher transparency of the decision making process;
- It allows the building of local capacities in the sector.

2.4.2. Barriers and Challenges Encountered in The Decentralisation of SWM Decisions in Tunisia

Despite its positive benefits and advantages, many barriers can be encountered in the process of decentralising decision making in local authorities related to SWM operations. These include:

- Conflicts between different parties, which can represent an obstacle facing the implementation of SWM programmes;
- Central government lacks trust in the accountability of sub-national governments for failure and fears that blame will 'default back' to ministers;
- Those leading decentralising reforms are often unsuccessful in taking the power and determining the local SWM strategy;
- In most cases, the non-acceptance of the national visions and orientations by the local decision makers.

2.5. General SWM Practices in Tunisia

Solid waste management is a considerable challenge facing the Tunisian government. The provision of adequate SWM services is critical because of its potential impact on public health, on the economy and on the environment. Population growth in urban centres, the lack of planning and know-how, lack of proper disposal, limited and inadequate collection service, the use of inappropriate technology and unsustainable finances are considered the main obstacles facing municipal SWM in Tunisia (Medina, 2002). Indeed, different types of solid waste are generated in Tunisia, which could be classified as industrial and households waste, or hazardous and non-hazardous waste.

Hazardous industrial waste: It is estimated that 150,000 tons of hazardous industrial waste is produced annually. The actors involved in the management of this waste are

ANGED (implementing the national strategy in the field and operation of treatment facilities) and ANPE (monitoring the application of the regulations), producers of hazardous industrial waste (industrial and private companies). For the treatment of hazardous industrial waste, three units were built in Sfax, Gabes and Jradou, with a nominal capacity of 90,000 tons/year. The activities at the centre of Jradou were stopped after the revolution due to a disagreement with the local population. The centre is actually in a phase of reopening after a long negotiation with the local citizens.

Non-hazardous industrial waste: This type of waste is collected and transported to controlled landfills operated by private companies. In 2010, the ten landfills at Tunis, Bizerte, Nabeul, Sousse, Monastir, Kairouan, Sfax, Gabes, Medenine and Djerba received 116.000 tons of non-hazardous industrial waste.

Used tires: The regulatory framework is defined by the governmental decree No. 2015-786 of 9 July, 2015, which fixes the terms and conditions for the management of used tires. Actually, 48,000 tons are produced and sold and the amount of used tires represents 16,000 tons. Fifteen percent of used tires (heavy weight) are retreated. Actually, a new approach is under discussion for the incineration of some used tires in cement plants to benefit from their calorific value (three tons of tires equates to two tons of fuel). Indeed, nine companies are authorised to collect and transport used tires, and there are five companies for their recycling.

Health care waste: According to ANGED, the total amount of health care waste produced by public health establishments in Tunisia is 16,000 tons per year; of this, about 43%, or 7,000 tons, is hazardous waste, and 9,000 tonnes is waste equivalent to household waste, which corresponds to a production of approximately 2.37 kg of health care waste per bed, per day.

Green and agricultural waste: The deposit of green waste from parks is estimated at 33,000 tons; the green waste from agriculture is estimated at 4 million tons/year, while the production of compost does not exceed 30,000 tons/year. Currently, only some composting stations exist in the country, mainly La Marsa, Gafsa, Djerba, Sfax, etc.

Demolition and construction waste: This type of waste represents a big problem to the Tunisian authorities as neither a law nor an infrastructure exists to govern it. Only some data exist in this sector, in some cities. For example, the total quantity of demolition and construction waste stored in 53 dump sites (controlled, authorised uncontrolled and wild) identified in seven municipalities of Greater Sfax is of the order of 432,000 m^3; in seven municipalities of Greater Sousse, it is of the order of 425,000 $m^{3;}$ and in the 34 municipalities of Grand Tunis, it is around 3,763,000 m^3.

ECO-Lef: is a public system of recovery and recycling of packaging waste that is implemented in partnership with local authorities. It consists of the collection of packaging waste under terms of conditions and agreements with ANGED, and the recycling of plastic waste under terms of reference and agreements for obtaining monthly quotas of these materials. This activity is highlighted in part 5.1.

E-Waste (WEEE): An application decree for electrical and electronic waste is being promulgated. The marketing in the sector represents 120,000 tons, with an annual output of WEEE waste of 100,000 tons. Currently, there are 11 companies for the management (collection and recycling) of computer equipment (4,500 tons/year). Furthermore, a pilot project, in cooperation with Koica (Korean Development Agency), for the treatment and recycling of WEEE has been established, but not yet exploited.

ECO-Batteries (Used Accumulators): The regulatory framework through the decree No. 2005-3395 of 6 December, 2005, is addressing the conditions and methods for the collection of used batteries. The regulatory framework, i.e. the decree of 23/04/2008, sets the terms and the amount of the mandatory deposit for the recovery of used accumulators used for transport means and for various industrial purposes. The 'Eco-batteries' system is financed by two modes: the establishment of a deposit system based on the type of battery, which seems to give a satisfactory result, and the eco-tax. Indeed, seven companies are authorised to recycle used lead accumulators. At the moment, more than 450,000 units per year are collected and recycled, of which 500,000 units are marketed locally, which represent 78%.

Eco-pile: The regulatory framework, decree No. 2005-3395 of 6 December, 2005, fixes the conditions and methods for the collection of used batteries (small batteries). The quantities of used batteries represent 62 million units/2,400 tons per year (70% of it from parallel markets). The average consumption is six units per person, per year. The authorities are currently collecting batteries from schools, commercial complexes and public institutions, and organising awareness days, etc. One authorised company for the recycling of used batteries exists; however, it not yet operational because of profitability issues. Meanwhile, ANGED is storing more than 400 tons of used batteries.

2.5.1. Solid Waste Collection and Transportation

The amounts of solid waste produced by the different sectors of the Tunisian economy continues to grow and puts pressure on the environment. A number of projects and infrastructure projects realised during the 1990s have helped to reduce this pressure. These projects and infrastructure concern mainly the collection, the transfer, the treatment and the disposal. The amount and composition of waste produced by Tunisian cities varies by location of cities and income level in one city.

Solid waste collection in Tunisia lacks a lot of organisation and coordination. The municipalities' collection systems are the same in most cities. Bins are common for both organic and non-organic waste, and no segregation of waste at the source is performed.

The use of containers is frequent in cities and they are considered to be inefficient. In addition, door-to-door collection services are rarely applied. The separation at source of organic material, paper, glass, metal, etc., is not yet developed, with the exception of a few small individual initiatives.

The collection rate is quite high: it is, on average, over 80%, and the total percentage of the population receiving waste collection services is between 60-90%; this is dependent on the nature of the area as large urban agglomerations receive a better service.

Road optimisation concepts of SWM have not yet been launched in Tunisian municipalities, whereby the existing waste collection systems have been developed based on limited data. The country also lacks facilities for the proper handling, collection and transportation of the generated wastes. A lack of proper transportation vehicles is also one of the problems facing SWM in Tunisia. On one hand, the number of available waste collection vehicles has decreased due to malfunctions or theft. On another hand, the traffic and the bad organisation makes the transportation of waste more time consuming and, as a result, more expensive and less efficient. Most of the vehicles used for transporting waste are often outdated, improper and non-functional.

2.5.2. Solid Waste Treatment and Landfilling

Actually, the treatment of 90% of MSW generated in Tunisia is performed through sanitary landfilling. The locations of these landfills were chosen according to the international standards. Indeed, the infrastructure was built by ANGED, financed by the government and operated by private companies. Waste disposal remains a problem in many cities and islands in Tunisia, since the closure of some landfills due to social manifestations after the revolution, and the unavailability of most of the landfills (without planning other options). Furthermore, all landfills (except Touzeur, Zaghouan and Djerba) are equipped with a degasification process, and the leachate treatment is generalised in all the existing landfills.

2.5.3. Recycling and Recovery of Packaging

In order to recover and to collect recyclable materials, the government has created ECO-Lef, which is the national system that is developing a formal recovery of packaging. Several formal companies for collection and recycling are working for the system; however, other formal companies are independent and are not members of the system.

The MLAE is encouraging municipalities to introduce recycling, reuse and recovery, but this is actually at a very preliminary stage. Several waste sorting at source projects have been developed since 2005 to demonstrate the advantages of this operation such as Hay El Khadhra, Sidi Bousaid, Djerba, Tunis. Unfortunately, all of these projects experienced failure after a period of operation due to financial and organisational problems. However, a new project will be developed in El Mourouj in 2020.

A recycling, reuse, and recovery active company does not exist in most cities in Tunisia. Waste sorting and recycling are driven by an active, informal sector. Referring to ANGED, about 5% of the total waste generated is recovered as recyclable materials such as PET, other plastics, metals and paper. These materials are sorted and collected from the waste containers installed in the street, and from landfills by waste pickers.

Actually, the government's vision is to ensure the transition to solid waste valorisation and to stabilise the organic fraction before landfilling to reduce GHG emissions. To this

end, the government has decided to build 18 mechanical biological treatment (MBT) plants in different cities. The MBT system represents a type of waste processing facility that combines a sorting facility with a form of biological treatment such as composting or anaerobic digestion. The starting of this project is planned with three MBT plants in Bizerte, Gabes and Sousse.

3. LITERATURE REVIEW ON SOLID WASTE MANAGEMENT IN TOURISM DESTINATIONS

A growing number of destinations have invested in tourism worldwide, turning it into a driver of socio-economic development through infrastructure development, enterprise creation, and of jobs opportunities and export revenues (UNWTO, 2017). During recent years, tourism has experienced a remarkable development and diversification to become one of the fastest-growing economic sectors. Indeed, international tourist arrivals and mobility are expected to increase between 2010 and 2030 by 3.3% a year to reach 1.8 billion by 2030 (UNWTO, 2018).

However, the development of tourism activities doubles the amounts of solid waste generated in various zones (Basak, 2007; Jiang et al., 2009; Cierjacksa et al., 2012), threatening the local environment due to improper SWM services. In most cases, waste generated from tourism areas ends in landfills and open dumpsites, contributing to the degradation of the environment and creating problems for the surrounding communities by way of smells, flies and litter (Kharbanda et al., 1990).

In many tourism regions, SWM is becoming a serious challenge, since large amounts of waste are generated, particularly by tourism accommodation establishments during the year or seasonally. In addition, the cost of ensuring a sustainable concept is considered high. Countries and regions where the economy is based on the tourism industry have become increasingly concerned about the environmental, as well as the socio-cultural problems, associated with unsustainable tourism. As a result, there is, at the moment, increasing agreement and discussions on the need to promote sustainable tourism development to minimise its environmental impact and to maximise the socio-economic benefits in tourist areas (Frederico, 2003).

This chapter presents a review of definitions and international practices and experiences in relation to SWM and tourism, as well as an examination of the composition of solid waste generated from tourism destinations and establishments, and the figures related to the financial framework and costs, etc. In addition, this chapter points to a review on the EPR system and international practices related to this principal.

3.1. EXISTING SWM PRACTICES IN TOURISM DESTINATIONS IN EUROPE

Tourism establishments are defined as hotels and similar accommodation such as restaurants, camp sites and marinas, and public structures such as museums, which offer services to visitors and tourists (Gruber et al, 2016).

Activities related to SWM in tourism areas cover solid waste collection from hotels and households, beach and street cleaning, infrastructure development for waste collection, and the treatment and valorisation as well as waste collection and recycling (Christina et al., 2006). SWM is considered to be one of the most relevant environmental aspects connected to tourism activities. As part of their businesses, tourism enterprises use large

quantities of single-use packaging and consumer goods, as well as large amounts of organic and food waste (Edmundo et al., 2015).

Referring to Edmundo et al. (2015), waste generation in tourism areas depends on many factors such as the type and occupation rate of the tourism businesses, tourists' attributes and season, and the environmental legislation at the national and local level.

Furthermore, beaches are considered an essential space for relaxation and holidays for both the local population, visitors and international tourists (Christina et al., 2006). Indeed, the exploitation of these spaces as tourism areas generates income, employment and promotes social benefits. However, population concentration at the coast has led to solid waste pollution on beaches, which significantly affects the tourism activity. Permanent residents and occasional or periodic visitors are equally responsible for the generation or inadequate disposal of solid waste in tourism areas and principally on the beach itself, especially during the summer (Zero Waste Europe, 2017). In fact, the inadequate infrastructure on beaches such as insufficient bins and containers, and the lack of collection and cleaning, represents a significant factor in the environmental degradation of these areas.

In addition, waste collected from street bins and street sweeping activities are considered a part of MSW. This consists of waste that accumulates from streets sweeping. For example, in Florence, Italy, the responsibility to collect this waste is also upon the local SWM authority and no significant seasonal variation in composition of this waste is visible (Gruber et al., 2016). In Copenhagen, Denmark, waste collected from street bins and street sweeping is not under the waste authority's administration, but falls under another department in the 'Technical and Environmental Administration of the City'. Regarding the case of Lisbon, Portugal, the collection of waste is carried out everyday and separately on the streets. However, a reinforcement in the equipment and in the collection frequency is planned by the municipality during the summer period (Gruber et al., 2016).

In most cities, tourism activities are concentrated in the summer period. In this case, municipalities organise special cleaning and collection services to collect large amounts of solid waste generated. For instance, in the city of Korčula, Croatia, where the waste streams and the categories are affected by seasonal variations, there is around 400% increase of mixed municipal waste in the summer season (in July and August) (Gruber et al., 2016).

Furthermore, there is a change in solid waste collection services during the year because of tourism activities. For example, from May to September, which represents the highest touristic season in Kavala, Greece, an increase in the number of employees and of the trucks plan for solid waste collection is registered (Gruber et al., 2016). In Copenhagen, the tourist flow is spread over the whole year and summer is considered to be a high season peaking in July. Indeed, no special collection service is organised in relation to

tourism except for reinforcements in connection with special events, festivals and concerts (Gruber et al., 2016).

The waste collection systems from tourism businesses differ from country-to-country, and from one city to another. Solid waste sorting at source in tourism enterprises depends on legal and organisational frameworks in the destination. For example, in Copenhagen, all tourism establishments are responsible for sorting their solid waste properly; they are also obliged to secure the documentation of the fractions that are actually being recycled (Gruber et al., 2016).

Solid waste collection is considered one of the essential operations to ensure a clean destination. In tourism areas, waste collection services are ensured for households and tourist establishments, which represent both the most important sources of waste generated. Solid waste collection is also provided in the streets and old towns; either from the installed containers, or after cleaning the littered waste. In many countries, both developing or developed, waste collection is performed as part of the pillar of SWM. The waste collection systems vary from one country (or city) to another (Mwanza et al., 2018).

Rodrigues et al. (2016) indicates that the implementation of waste collection systems in tourism areas affects public health, the quality of the area and the recovery of materials for recycling and reusing purposes. However, in developing countries, waste collection is mainly performed by manually depositing waste in bins, followed by transportation by vehicles to transfer stations or directly to landfill (Amponsah et al., 2004).

The elaboration of waste collection systems in tourism destinations should not be considered in isolation of sustainability. Specific attention should be paid to whether the selected waste collection system is economically, environmentally and socially sustainable (Carchesio et al., 2015). Indeed, it has been identified that these waste collection systems contribute to sustainability through more waste reduction, costs optimisation and improving the quality of recovered materials (Mwanza et al., 2018).

As an example, Figure 3-1 represents the solid waste collection service from hotels in Rostock, Germany, where private companies are in charge of collecting recyclable materials from hotels and other tourism accommodation establishments. However, the public sector is responsible for collecting residual waste, which could also be attributed, in some cases, to private companies. Due to the clear and legally fixed regulations in Germany, there are hardly any deficits in the solid waste disposal. Since the composition of the accumulated residual waste generated from hotels and other tourism establishments is similar to the waste from private households, there are no specific requirements for its disposal; the only exception to this is the disposal of food and kitchen residues with animal ingredients or animal origin, which must be stored and disposed of separately.

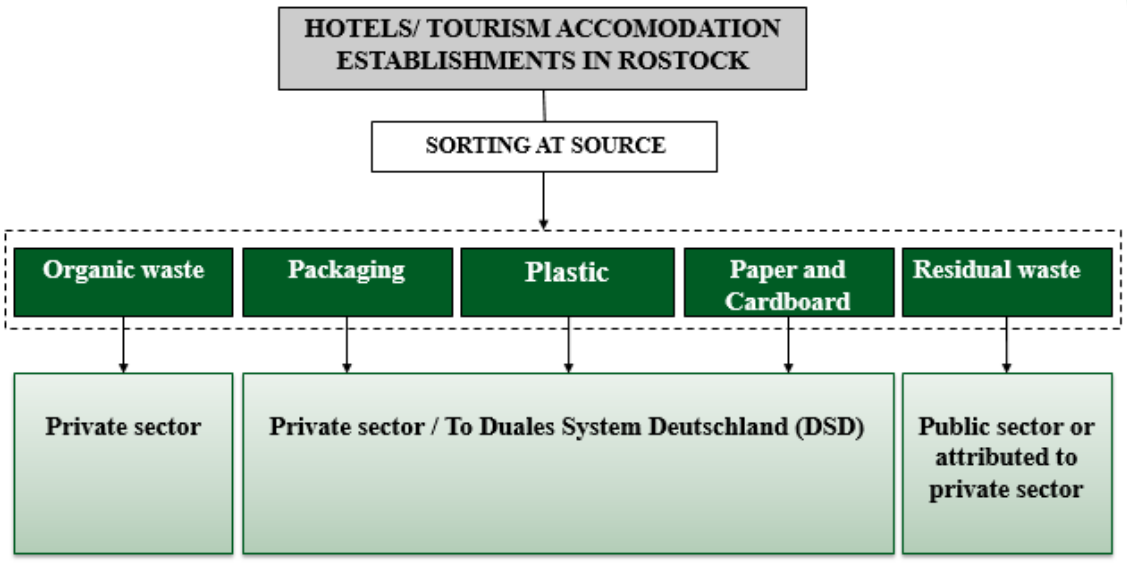

Figure 3-1. *Solid waste collection system from hotels in Rostock - Germany*

3.2. BEACH CLEANING IN TOURISM DESTINATIONS

Beach cleaning is defined as a service provided by the municipality to eliminate waste material from identified swimming beaches, as well as the cleaning of associated luxuries (Overstrand Municipality, 2014). This activity plays a vital role in maintaining a high standard of coastal zones that contributes to the improvement of social and economic value of the coast. The same reference indicates that the identification of swimming and normal beaches is crucial to make priorities for the cleaning.

For instance, the Dubai municipality uses automated beach cleaning equipment in addition to the manual cleaning of some parts of the beach. The municipality has created a 'beach cleaning team', comprising 49 cleaners and 7 supervisors, to provide daily beach maintenance services. In order to control any infraction caused by people littering, and to enhance the efficiency of cleaning of many zones with difficult entry, the municipality uses a drone based method (Construction Week Online, 2016).

In Limassol, Cyprus, beach cleaning takes place over the whole year by the municipality. Between April and October, high season, cleaning takes place twice a week; however, the beach is cleaned only once a week during the remaining low season period. The activities include emptying the waste bins, collecting large and small pieces of litter (e.g., cigarette butts) manually, and through an automated specialised vehicle and machines (Limassol Municipality, 2006).

3.3. INDICATORS DEVELOPMENT FOR SWM IN TOURISM

Indicators are considered a tool with which more information and data can be obtained. The 1992 Rio Conference on Environment and Development highlighted the demend for better and greater knowledge and information about environmental conditions. To achieve this, it was necessary to collect concrete data, as well as to promote new research and innovations with regard to indicator frameworks. The selection criteria ensure that

indicators are utile and effective in their provision of information to decision makers (Segnestam, 2002). However, and as Bahia (1995) reports, 39% of indicators can be easily accessed, 39% present moderate difficulties in obtaining data, and the remaining 22% are grouped as being difficult to answer. Furthermore, Rosenstrom (2002) finds that environmental indicators do not steer decision making in Finland, but rather supply background information.

As an example, the Urban Waste project aims to support policy makers in relation to SWM challenges. It intends to help them develop strategies that reduce the amount of municipal waste production; that support the reuse, recycling, collection and disposal of waste in tourist cities in Europe; and provide selected suitable and practicable indicators to calculate the status quo assessment of SWM in these zones.

Furthermore, Ceron et al. (2003) show that indicators for sustainable tourism may exist at national, regional and local levels, and that they have socio-cultural, economic and environmental dimensions such as waste volume produced by the destination (tones per month), the volume of waste recycled (m^3)/total volume of waste (m^3) (specified by different types) and the quantity of waste strewn in public areas (garbage counts).

In addition, the results of the workshop on 'Sustainable Tourism Indicators and Destination Management' in Kolašin, Montenegro, in April 2007, developed basic key indicators of status such as total weight of waste to landfill per month, ratio of weight of waste to landfill in tourist season compared with non-tourist season, average weight of waste to landfill per resident, monthly weight collected in clean-up campaigns, observation (count) of litter on sample road stretches and tourists' perception of cleanliness of the area (UNWTO, 2018).

Developing different indicators for different audiences, contexts and ends represents an important parameter. Additionally, special attention should be paid to interpreting the collected and developed indicators to transform this into information. This can be used as a tool to support decision makers in planning, monitoring and judging specific policies, as well as to improve SWM services in tourism zones (Ristić, 2005).

3.4. TOURISM WASTE CHARACTERISATION AND QUANTIFICATION

On the global scale, solid waste generation by tourism has been highlighted by the United Nations' Environment Programme (Crompton, 2012). In fact, the UNEP estimated a worldwide solid waste generation of 4.8 million tons just from international tourism, which represents about 14% of the total MSW generated during the same year. Solid waste generation is nowadays considered as one of the most relevant environmental aspects from touristic activities, particularly owing to the fact that many tourism establishments that make up this sector such as hotels, bars and restaurants use large quantities of inessential single-use goods and packaging as part of their activities (Edmundo, 2015).

As an example, MSW generation rates in tourism cities has reached 0.88 kg per inhab/day in the Czech Republic, 1.04 kg per inhab/day in Chile, 1.45 kg inhab/day in France, 1.53

kg per inhab/day in Austria, 1.64 kg per inhab/day in Germany, 1.75 kg per inhab/day in Australia and 2 kg per inhab/day in the USA (Edmundo, 2015).

However, the UNEP has estimated that European tourists generate about 1 kg per tourist per day of solid waste, while tourists from the USA could generate up to 2 kg per tourist per day. Edmundo (2015) highlights that there is a broad range of waste generation in tourism areas, varying between 1 kg and 12 kg per guest per day. This variation depends on the type and occupation rate of touristic installations, tourists' attributes, season of the year and the environmental legislation in the country (UNEP/WTO, 2005).

With regards to waste quality, the composition of solid waste generated from tourism businesses is very similar to the waste from private households. Small registered differences are related to the separate collection and disposal of waste and the relatively higher amount of light packaging and food waste (Ofner, 2011). The generated waste quantities, its composition and the resulting costs depend on many factors and vary from one company to another.

The purpose of sorting analyses of waste is to profile the types of materials generated. Findings of such studies are useful to provide a basis for measuring the effectiveness of existing diversion programmes, determining what materials continue to be landfilled, and developing new strategies. Several sorting analyses studies in tourist destination have been conducted in this direction. Table 3-1 presents a review of some international experiences.

The amounts and characteristics of MSW differ not only from country-to-country, but also from one tourism area to another and neighbourhood-to-neighbourhood, even within the same city. These differences depend on socio-economic structures, income levels, and the consumption and usage habits of people (Khan et al, 2016).

The presence of tourism business could also have a hand in the change of the composition and the amounts of waste generated. These establishments generate the presented fraction from different departments of the enterprise. Following Zein et al. (2008), non-hazardous waste fractions are generated from all hotel departments, for instance, the purchasing department, administration, garden, reception, guest rooms, restaurants and bars (see Table 3-2). This list of fractions is not exhaustive, although they do mention all of the most significant components. For instance, other types of waste such as bulky items (e.g., furniture), construction and demolition waste (e.g., concrete, pipes, etc.), discarded electronics and office appliances, and used refrigerating equipment are also generated occasionally.

Table 3-1. *Results from various studies on the hospitality industry waste characteristics.*

Study areas	Study period	Waste composition	Data source	Reference
Vietnam	2018	Biodegradable waste accounted for the highest percentage of 58.5%, includes 35.5% kitchen waste, 15.5% garden waste and 7.5% tissue paper. Recyclable waste accounted for about one-fourth of total waste, which consists of 1.2% of metal, 4.2% of cardboard, 12.9% of plastic including plastic bags, 0.8% of PET bottles, 2% of glass and 4.7% of the paper.	120 hotels were sampled from Hoi An	(Pham et al., 2018)
New York	1996	39.9% paper, 27.8% food /organics, 7.6% glass, 7.0% plastic, 6.7% yard waste, 6.1% metal, 4.3% other, 0.2% hazardous waste.	Waste composition for the New York City hotel industry	(Winter & Azimi,1996)
Los Angeles	1991-1993	46% food waste, 25.3% paper, 11.7% cardboard, 6.7% plastics, 5.6% glass, and 4.5% metals.	Study of 25 hotels	(Evans, 2008)
United Kingdom	2009-2010	41% food waste, 13% paper, 9% cardboard, 10% plastics, 14% glass, and 13% other.	Study of 138 hospitality industry businesses	(WRAP, 2012a, WRAP, 2012 b)
United Kingdom	2012	37% food waste, 18% paper, 7% cardboard, 15% plastics, 10% glass, and 13% other.	Study of 35 hotels	(Parfitt et al., 2013)
Paro region of Bhutan	2017	53% organic waste, 14% glass, 9% paper, 7% metal, 7% LDPE, 5% textiles, 3% HDPE, 1% rubber, and 1% other.	30 hotels	(Zangmo & Sharp, 2017)
New Delhi, Noida, Greater Noida, Ghaziabad and Gurgaon	2013	61.2% food/wet waste, 0.8% plastic PET bottles, 1.5% other/mixed plastic, 0.5% tetrapak (laminated paper), 0.47% aluminium, 14.8% glass, 6.1% newspapers, 0.7% mixed office paper, 13.7% cardboard, 0.2% trash (laminated plastic).	Study of 8 hotels	(Nath, 2014)
Malaysia	2007	71.73% organic waste (food waste), 5.77% paper, 8.06% cans, 5.07% plastics	10 restaurants	(Majid, 2007)

		(bottles/bags), 2.68% glass, 5.13% yard wastes, 1.56% other.		
Phnom Penh, Cambodia	2014	56.70% biodegradable, 19.32% plastic, 14.84% paper, 8.14% inorganics, 1.25% textiles and shoes, 0.25% rubber and leather, and 0.01% wax.	Waste from hotels, restaurants, internet cafes, guesthouses	(Mongtoeun & Fujiwara, 2014)
Greece	2015	Recyclables (mainly glass, plastics, cardboards and metals) is the dominant fraction (52%), followed by organic waste (45%). 60-80% of this could be valorised through reuse, recycling and composting activities	Composition of waste in a Greek all-inclusive hotel	(Mavropouls, 2015)

Table 3-2. *Types of solid waste generated in hotels (Zein et al., 2008).*

Waste fractions	Components	Source (departments)
Household waste	Food/kitchen waste, used or dirty paper and wrapping, plastic wrapping or bags, composite wrapper	Hotels' different departments
Cardboard	Packaging	Hotels' purchasing and other departments
Paper	Printed documents, brochures menus, maps, magazines, newspapers	Administration, reception, guest rooms, restaurants
Plastic	Bags, bottles, households goods, individual portion wrappers for various products	Kitchen, restaurants, bar, guest rooms, administration
Metal	Tin cans, food containers, aluminium packaging	Kitchen, restaurant, bars, guest rooms
Glass	Bottles, flasks	Kitchen, restaurant, bars, guest rooms
Cloth	Tablecloths, bed-linen, napkins, clothes, rags	Kitchen, restaurant, bar, bathrooms, guest rooms
Wood	Wooden packaging, pallets	Purchasing department
Organic waste	Fruit and vegetables, peelings, flowers and plants, branches, leaves, grass	Kitchen, restaurants, bars, guest rooms, gardens

Following Zein et al (2008), large amounts of hazardous waste are generated from hotels such as ink cartridges, IT disks and CD's, batteries, fluorescent lights, etc., which must be collected and stored separately.

3.5. SWM PRACTICES IN TOURISM ESTABLISHMENTS

The waste hierarchy is a central principle of SWM, which includes the prevention, precaution, and polluter-pays principles (Lazarevic, 2010). It is the part of the framework that requires businesses to prioritise their management strategies (Figure 3-2). This model provides an exhaustive understanding of SWM because it supports businesses to categorise SWM strategies and to choose the most suitable ones by connecting the needs of hotel guests with the needs of the local authorities and the environment (Chertow, 2000).

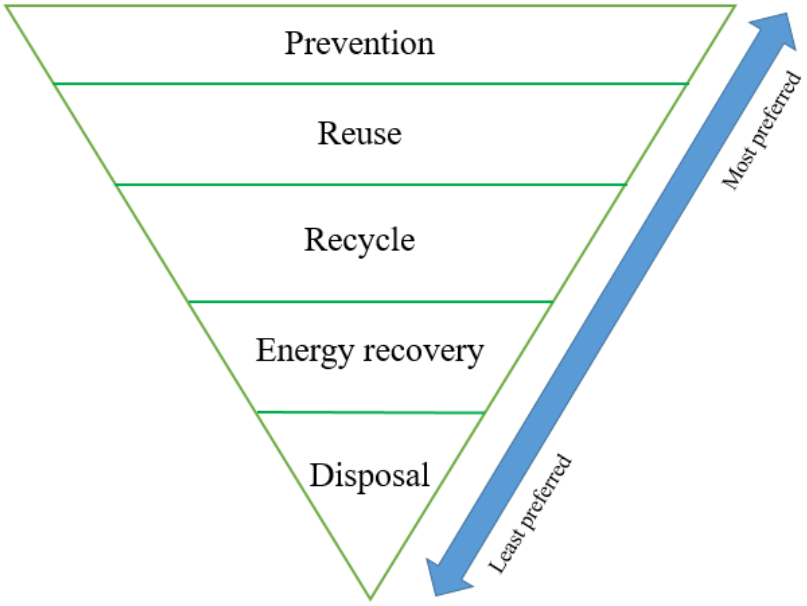

Figure 3-2. *Waste hierarchy scheme (WRAP, 2015).*

Currently, in many developing countries, regions or cities, the bottom-up model is applied. This means, in the absence of the recovery infrastructure and environmental culture, as well as the lack of expertise to prevent the waste, to reuse and to recycle, the sanitary disposal of solid waste is the first solution to avoid social, environmental and economic effects of mismanagement.

Some studies indicate that the level of involvement of hotels in SWM strategies depends on the size of the hotel (Buckley & Araujo, 1997; Pigram & Wahab, 1997; Mowforth & Munt, 1998), their connection to multinationals (Bohdanowicz, 2005b; Rivera, 2004), and the class of the hotels (Bohdanowicz, 2005a). On the one hand, large enterprises are more ready and involved in SWM programmes because they have more visible environmental impacts (Irene & Perry, 1999), are better equipped and have available resources to invest in environmental protection (Sanjay & Harrie, 1998), and they prefer going to the re-use, recycling or valorisation of waste. In addition to that, they receive stronger pressures to establish actions to face environmental pollution from various stakeholders (Branzei et al., 2002).

On the other hand, small hotels are fewer engaged with SWM programmes because they have limited resources or internal structures to ensure an effective SWM (Brian, 2005). These enterprises consider that they are only generating small amounts of waste.

Moreover, they lack clear and adequate knowledge about environmental and SWM practices.

Following Vinod et al. (2002), large enterprises are more engaged than small-scale establishments in eco-labelling activities. Small businesses are, in most cases, unable to meet the strict standards set by eco-labelling conditions, caused principally by the lack of financial means or spaces. Furthermore, Paulina (2005) confirms that chain businesses have more expertise and experience related to good environmental management initiatives than independent establishments.

In addition, waste mapping is considered a strategy that is being more and more used by organisations and tourism businesses to ensure more efficient SWM systems. It helps establishments to understand how and where waste is produced, and to calculate possible costs. A waste map is created to reflect these data. The business can subsequently plan its SWM operations in a more efficient way (Pirani & Arafat, 2014). Results confirm that waste mapping is crucial tool that allows hotels to identify sources, types and quantities of waste produced. The process will help hospitality industries to prioritise areas where simple actions can be taken to minimise waste, save money and achieve sustainable waste management. This method, for all types of organisations, is gaining reputation around the world in countries such as India (Green Yatra NGO, 2014).

3.6. KEY OPERATIONAL COSTS OF SWM IN TOURISM DESTINATIONS

Tourism is a key generator of solid waste during the year and raises concerns about possible extra costs and SWM systems' potential to manage these amounts (Altinay & Hussain, 2005). Greco et al. (2018) find that the increase in the number of tourists, the number of overnight hotel stays and tourists' spending all significantly increase the waste collection costs. The same authors analyse a sample of 68 Italian municipalities; they estimate that tourism increases the paper, paperboard and multi-materials collection costs.

Moreover, Mendes et al. (2013) analyse SWM costs in a seasonal tourism area of Portugal; they analyse a set of 24 performance indicators to evaluate the impact of tourism and seasonality on SWM. They find that the collection cost is considerably higher during high season compared with low season.

On the business level, several tourism accommodation establishments underestimate the SWM costs in their businesses, considering it as a disposal cost. In cases where municipalities charge fixed fees for waste collections based on the maximum occupancy level or a general tax based on the turnover (Chaabane et al., 2018), waste prevention, reduction and recycling measures will have no impact on the financial scale (no motivation for the establishments to sorting at source). The real cost of SWM is often significantly higher than just the collection and disposal cost such as staff costs, infrastructures, street and beach cleaning, communication, etc.

However, the installation of appropriate waste-handling equipment and staffs' efforts to sort different waste fractions acquire costs that will, somewhat, generate benefits of lower collection and disposal charges. Table 3-3 presents the case of one hotel in Freiburg,

Germany, which is charged for removal of all waste except cardboard, for which a significant payment is received (Styles et al., 2013). The table indicate that the hotel pays for the transport and the disposal of all types of sorted waste generated, expert the disposal of cardboard packaging, which is sold to specialized companies.

Table 3-3. *Waste management costs for a hotel in Freiburg in Germany.*

Fraction	Volume	Transport	Disposal	Total
	Tons/year	EUR/Tons		EUR/Year
Residual waste	148.18	30.37	95.63	18,656.14
Building rubble sorted	7.88	11.68	6.50	143,22
Wood packaging	10.22	77.10	9.12	881,24
Mixed construction waste	10.16	18.11	91.96	1,118.30
Cardboard packaging	59.16	20.14	-61.60	-2,352.85
Glass	50	28.76	4.63	1,669.54
Food waste	116.64	NA	103.69	12,094.00
Light weight recyclables	18.4	49.32	93.01	2,618.96
Fat from grease traps	28.9	84.78	41.18	3,640.00
Container rental	-	-	-	4,640.00
Total				**43,008.55**

Referring to Umweltpakt (2002), a hotel in Germany with 100 rooms and 180 beds can save about 8,500 euros per year on disposal costs through sorting, selecting suppliers and avoiding waste. For example, and as a result of the reduction of waste volume by a garbage press, one hotel in Berlin was able to halve its collection costs and, consequently, the disposal costs fell by half (EU Recycling, 2017). With an assumed container size of 1100 litres, this can mean savings of 2,772 euros a week (Erbenschwanger, 2015). From the distribution of waste generated by 36 hotels, from two stars to four stars, 63% of the waste was from residual waste and 28% from organic waste (Hamele & Eckardt, 2006). This shows the importance of reducing this fraction by avoiding and sorting at source.

In Germany, the used containers are based on the size of the tourism enterprise. The recyclable material can be disposed of by private collection companies where the cost depends on the offer provided by the companies' candidates. As a rule, collection contracts are agreed for a minimum of two years to provide a degree of security for both parties, but also to guarantee the possibility of regular renegotiations, even if market price fluctuations occur. It is worth noting that, in some cases, for recyclable materials such as paper, light packaging, glass and scrap, only the cost of treatment, per ton of waste, will be charged to the customer. For the delivered quantity of residual material, the customer usually receives a separately agreed remuneration. In Rostock, for example, the service

of residual waste collection is provided by the municipality, which itself can establish a call for private companies.

Since hotels have the choice of the company for the disposal of recyclable materials, they have good opportunities for individual price negotiations. Nevertheless, every establishment should strive to reduce or separate its waste as much as possible in order to dispose of it via recyclable fractions, which costs less than residual waste.

3.7. FINANCING OF SWM IN TOURISM DESTINATIONS

It is increasingly recognised that SWM is more than just waste collection and transportation to landfill. Waste treatment, and street and beach cleaning cost as much or more than collection and transport. With the economic and urban population growth, the quantity of waste to be managed will increase, and the cost of SWM will increase even more rapidly (Appasamy & Nelliyat, 2007).

The SWM activities in tourism destinations are mainly financed by municipalities. In many countries, SWM activities in tourism are only financed through local taxes (property tax). The waste generators such as hotels, restaurants, and so on, could pay special or general fees for SWM services. However, paid fees do not always cover the costs of the municipality. In some cases, tourists can absorb charges for the cost of the solid waste generated per night of their stay. Furthermore, some tourism municipalities are financing part of their SWM activities via the EPR system. Figure 3-3 represents the possible source of revenues for tourism municipalities to finance SWM activities.

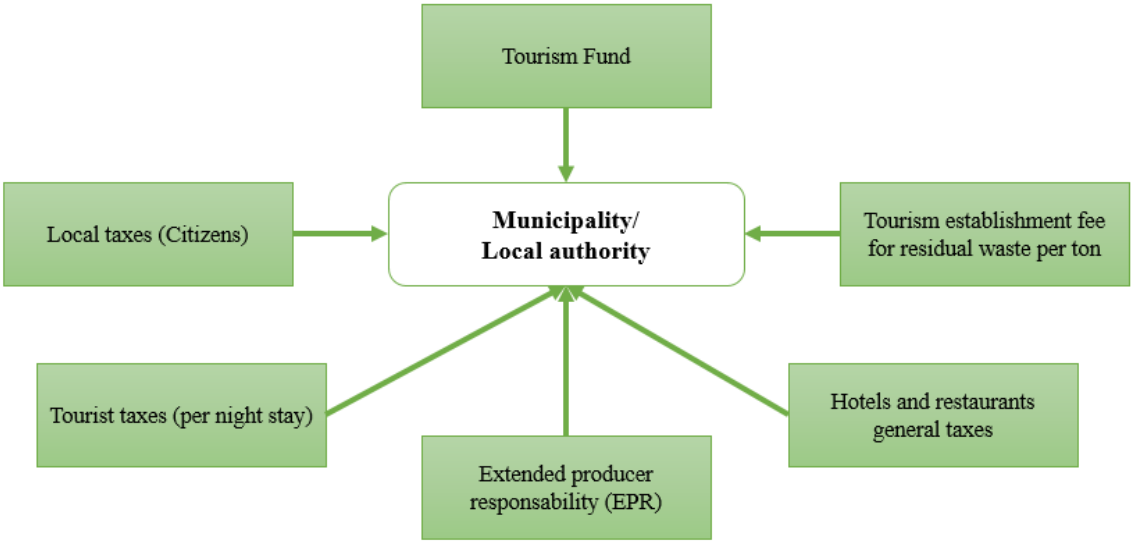

Figure 3-3. *Financing of SWM activities in tourism areas*

Tourism destinations' SWM activities cost more than those of other cities because it requires more financial resources to cover the costs and to ensure a clean area. For instance, authorities in the Indonesian island of Bali, in 2019, are considering introducing a tourist tax to help address the rising tide of waste. The regional government in Bali has drafted a law to impose a fee of 8.83 euros on visitors when leaving the country (Deskin, 2019). On the other hand, the island's environmental NGO, the 'Gili Eco Trust' (GET)

manages a tourist eco-tax by which a 6 USD fee is collected from tourists by shops and other tourism businesses on behalf of the GET to provide funding for tourism sustainability projects (Willmott & Graci, 2012).

Moreover, several municipalities in Italy already set a tax on overnight hotel stays to cover the municipal services used by tourists including SWM (Beth, 2019). This tax is important to avoid further taxes on local citizens. In Nice, also, hotels covered by MSW collections, that previously were collected for free, are currently being charged a special fee for the collection service (Gruber et al., 2016).

The SWM tax could also be applied to local citizens on services for mixed and non-mixed MSW to finance the SWM operations. For example, an analysis of the waste taxation in Canton of Vaud, a tourism region of Switzerland, shows that taxing waste generates benefits worth 36% of SWM costs (Stefano et al., 2016). In Jordan, for instance, a waste tax was included in electricity bills. In addition, in many tourism municipalities in Finland, a smaller fee is charged for waste that is sorted and fit for use, as opposed to mixed municipal waste that needs expensive treatment. The aim is to encourage the public to reduce waste, make it less harmful, and utilise it.

Some other countries such as Grenada have developed an EPR system based on the deposit-refund system in order to guarantee more finances for the SWM operation and, in consequence, to ensure a clean destination.

3.8. EXTENDED PRODUCER RESPONSIBILITY CONCEPT FOR PACKAGING

The supply of goods has drastically changed over the last 50 years. The multitude of products is increasing everywhere. Exchanging goods is no longer limited to the domestic market in every country around the world. Moreover, large amounts of waste are generated and treated in different manners and the consumption of products and services affects the environment in many different ways (European Environmental Agency, 2016). The objective is to shift towards recycling and reuse (Ferrão et al., 2008) to reduce production costs, save energy and resources, and create employment opportunities (Nahman, 2010).

In recent times, the international orientation is focusing on developing the EPR concept, which makes the producers responsible for the product during its life-cycle (Driedger, 2008; Nahman, 2010). This system is based on the polluter-pays principle, and encourages the environmentally friendly design of the products (Charles, 2004; Ferrão et al., 2008).

The Organisation for Economic Co-operation and Development (OECD) defines EPR as an environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product's life cycle including its final disposal (OECD, 2001; Walls, 2006). This approach moves the financial or physical responsibility of recycling to the upstream producers and calls for incentivising the producers to incorporate environmental considerations into product design (OECD, 2001; Walls, 2006); both the producers and the consumers are the waste generators. The incentives

provided by this system also encourage changes in consumer behaviour (Nahman, 2010). Furthermore, EPR includes both the upstream and downstream stages of the product life cycle.

Referring to the practical manual developed by the United Nations (UNEP, 2018) on EPR, a producer is either the entity whose brand name appears on the product itself or the importer. A producer is assumed to be in the best position to improve products by determining product design and material selection and having access to the most precise information on their products. They must also exercise strong leadership throughout their product supply chain in order to establish an efficient recycling system and to promote environmentally sound product design.

Several EPR systems exist worldwide in both developed and developing countries. The differentiation between different practices and experiences is related to the organisation of the system operator, the definition of the producer, the exemptions for paying and motivations, the role of municipalities, the involvement of the informal sector for the case of developing countries, and the free riders, etc. (Bünemann et al, 2018).

First, the Producer Responsibility Organizations (PRO) as non-profit organization are responsible of the obliged producers. This concept is in place, for example, in Belgium, France, Italy, the Netherlands and Spain, where the municipality is in charge of the waste collection while the system operator cover the costs and transfers the funds directly to the municipalities. The organisation is in charge of all kinds of packaging waste in Belgium and the Netherlands. They are, however, responsible for only packaging waste generated in households (Bünemann et al, 2018).

However, the producer responsibility organisation could be for-profit such as in Germany and Austria where the EPR systems have changed and developed from having a single organisation to competition between several organisations. Since the producer responsibility organisations are private companies, they are not the responsibility of the obliged industry; however, each obliged producer has to contract an organisation of their choice for the management of their packaging. In addition, in these countries, the EPR system exists in parallel to MSW management and local authorities are not part of it (Bünemann et al, 2018, Yamini & Samraj, 2015).

In Germany, the law obliges producers to either individually recuperate their packaging waste for recycling and treatment or to join the system operator (Duales System Deutschland [DSD]). Producers pay the DSD annually to use the green dot label. They are, at the same time, responsible for ensuring high recycling rates according to the fixed objectives. By obligation, the paid fee is based on the type of material and its weight. Such a fee system, in which low fees are applied for highly recyclable material, directly influences producers' decisions and choices of material for packaging, and supports the innovation initiatives aiming at the improvement of the packaging design.

As an overview of packaging types collected and recovered by EPR systems in European countries, it should be indicated, for example, that each year in Germany, about 2.4

million tonnes of lightweight packaging, about 2 million tons of paper/cardboard, and more than two million tons of glass are collected via the EPR system (Bünemann et al, 2018). In Belgium, the producer responsibility organisation recycles around 90% of all packaging put on the Belgian market annually and has now created about 2,500 job opportunities. In France, the organisation was able to gather 9.5 million euros for packaging waste management activities, from the collection, to the sorting and recycling, and has recycled 56 million tons of packaging waste. Finally, in Spain, since 1998, the organisation has managed to recycle 19.3 million tons of packaging and has generated 42,600 jobs in Spain, over 9,400 of them directly (Bünemann et al, 2018).

3.9. BENEFITS OF EFFICIENT SWM SYSTEMS IN TOURISM

The SWM sector is a challenge that faces many cities around the world (Abarca Guerrero et al., 2012). However, establishing integrated SWM strategies, like recycling, composting and waste-to-energy, play an important role in reducing GHG emissions by recovering materials and energy from the mixed MSW stream (Kong et al., 2012). In addition, there is still a possibility for potential reduction in the carbon foot print of the solid waste sector, as the carbon reduction is not fully exploited, where the sector can be the opportunity to change from a net emitter into a net reducer of GHG emissions (International Solid Waste Association, 2009).

Current trends in European waste policy aim at reducing the deposition of biodegradable wastes in landfill sites (Council Directive, 1999/31/EC). Only when residual organic materials cannot be used are they disposed of or utilised for energy production. In this context, the recycling of these materials shall help to protect natural resources (Hüttl & Fussy, 2001).

In Germany, for example, GHG emissions from the SWM sector decreased from 38 million Mg of CO_2-eq in 1990, to about 18 million Mg of CO_2-eq in 2006, which is due to the introduction of the MBT and source separation. In the United States, increases in recycling and composting of MSW between 1974 and 1997 have resulted in avoiding more than 1000 kg of CO_2-eq (Weitz et al., 2002).

The results of the study elaborated by Turner (2015) indicate that the recycling of source-segregated waste materials result in net GHG emissions savings. The avoided GHG emissions from the recovery of high frequency materials such as LDPE, PET, textiles, steel cans, and aluminium cans were found to be notable, highlighting the importance of effective source-segregated recycling of key waste materials in reducing the GHG impacts of SWM.

The main benefits of recycling are the reduction of material transportation and disposal costs, getting cheaper materials compared to virgin materials and the preservation of landfill capacity, which aims to the elongation of landfill design life. Recycling helps in greening our infrastructures by conserving natural resources, decreasing energy use, reducing GHG emissions and air pollution, reducing the extraction of the virgin materials and minimising their consumption (Sojobi et al., 2016).

3.10. CHALLENGES AND BARRIERS TO SUSTAINABLE SWM IN TOURISM AREAS

Developing an integrated SWM system ensures several financial advantages to the tourism accommodation sector. First, reducing the amount of solid waste generated automatically reduces costs related to its disposal, transportation and treatment (Todd & Hawkins, 2001). Second, minimising waste at source also means fewer consumed resources (Pirani & Arafat, 2015). In addition, developing green strategies creates a positive image for the establishment and the destination generally, leading to improved relations with stakeholders, the local population and guests (Ball & Taleb, 2011). Furthermore, waste reduction, waste sorting at source and recycling activities (by the industries or citizens) could support the efforts of the local government and could reduce investment costs such as treatment technologies, sorting technologies, etc.

However, there are many barriers facing SWM in the tourism sector. First, some hotel managers are not interested in implementing policies. This is especially the case in either smaller properties, for example, those that contain fewer than 30 rooms (Radwan et al., 2010) or fewer than 50 rooms (Main et al., 1997). The challenges for these hotels include:

- The inability to generate sufficient amounts of waste for SWM companies to be interested in collecting and recycling, since the transport costs are expensive;
- A lack of time among managers and employees to manage it;
- A lack of space and financial means to install the necessary infrastructure.

Furthermore, Pham et al. (2018) examine the possible barriers that SWM (composting and recycling activities) can face in tourism areas through the elaboration of a survey with 120 hotels in Vietnam. Results show that the barriers include the lack of information and skills, and the lack of space for collecting and for the storage. In addition, the operation could take a long time. Some hotels consider it an unsanitary operation that they can do in a hotel space. Gruber et al. (2016) indicate that hotels are blocked by the SWM infrastructure in their locality, which is commonly owned and operated by the local authority, especially if there is no other purchaser for recyclable materials that are not collected by the local system. Furthermore, Chen et al. (2005) indicate that small islands often have difficulties finding markets for the re-sale of recyclables. The problem is often the transport cost off of the island for treatment or recycling.

The important parameters that could support a sustainable SWM concept in tourism areas include the location of the property (municipality) and the availability of sorting and recycling facilities in its locality that are willing to participate in recycling programs, and effective employee education programmes. Furthermore, a study carried out in the United States found that the waste disposal fees was among the most important factors. This was followed by a positive public image and then legislative restrictions. The least important factors affecting sustainable SWM were a corporate policy and guests' demands (Shanklin et al., 1991). In addition, changes in policy and regulation, followed by proper enforcement and monitoring, also represents an important step towards ensuring a sustainable SWM in tourism areas (Ball & Abou Taleb, 2010).

4. KEY INDICATORS DEVELOPMENT AND DIAGNOSTICS OF THE SOLID WASTE MANAGEMENT IN TOURISM IN TUNISIA

The rapid development of the tourism industry has a direct impact on the increase in the amount of solid waste in tourism areas (Giurea et al., 2018; Arbulu et al., 2017) and has a negative impact on the environment (Murava & Korobeinykova, 2016), namely in the form of higher operational costs (Greco et al., 2018), blight owing to litter and contaminated water, and a reduction in the touristic value of otherwise attractive locations (Edmundo & Rodrigo, 2015). This has increased pressure on public authorities to develop efficient municipal solid waste management (MSWM) policies and systems to deal with the impacts on services related to solid waste generation in tourism destinations (Al-Khatib, 2010; Foo, 1997; Bartone, 1990).

The objective of this chapter is to provide a core set of organisational, technical, financial, legal and social indicators that have the greatest influence on decision making. The most important indicators for the Tunisian context are employed to diagnose the SWM situation in the tourism sector. Based on these indicators, possible organisational, financial and technical solution are developed.

The lesson learned from this chapter is to take into consideration the importance of developing different indicators for different audiences, contexts and ends. Moreover, special attention should be paid to interpreting the collected and developed indicators to transform this into information. This can be used as a tool to support local authorities in decision making, planning, monitoring and judging specific policies, as well as to improve the SWM sector in tourism zones (Ristić, 2005).

4.1. MATERIALS AND METHODS

4.1.1. DATA COLLECTION AND INDICATORS DEVELOPMENT

As a first step, and to further identify more drivers, a review of relevant papers, reports, and doctoral theses on SWM in tourism was undertaken (see reference 142 to 162). The literature review acted as a base from which to learn from other researchers, best practices and international studies to better prepare all the possible items contained in this chapter and the questionnaires (see the questionnaires directed to hotels and municipalities in the Annexes I.2 and I.3).

Both questionnaires were structured to support the development of appropriate indicators, and to collect more data on the Tunisian context. The first questionnaire (Annex I.2) concerns hotels and includes questions on the satisfaction of the establishment in terms of waste management in the zone, as well as technical aspects including storage, collection, sorting, composting, existent infrastructure, etc. In addition, the questions concern the contribution of the hotel and its staff to the SWM system. The second questionnaire (Annex I.3) concerns municipalities, which are considered the first parties responsible for waste collection and the cleanliness of tourist destinations. Questions

include the role of public and private sectors, the type of waste collected, and the financial aspects of SWM (collection costs, taxes paid by hotels, role of the tourism fund, etc.).

As a second step, the employed methodology for the development of the indicators was based on a participatory process (Segnestam, 2002). First, the framework was developed, agreed upon, and harmonised to structure what is to be monitored. Then, the selection criteria, indicator sets and analytical tools were defined to establish a clear initiative that can be communicated to various stakeholders. Finally, the practical phase was initiated to collect data through questionnaires, visits and analytical tools.

In this chapter, the most important indicators for the Tunisian context were selected based on the country's current framework. In addition, the ability of the indicators to influence decisions and to improve the sector was analysed. To this end, key individuals from hoteliers, private companies, and national and local authorities were employed to identify current SWM practices.

4.1.2. Theoretical Quantification

The annual quantities of waste generated by the tourism sector in Tunisia were calculated based on estimating the amounts of solid waste generated by tourists (Qwt). First, the average length of stays in accommodation units for a city and a commune were calculated using the following formulas, which were developed by Florin (2013):

$$Ds = Nn/Na \quad (1)$$

where **Nn** = number of overnight stays; Na = number of arrivals.

Then, the amount of solid waste generated by tourists was calculated based on the formula:

$$\mathbf{Qwt} = Nt \times Itwg \times Ds/1000 \text{ (t/year)} \quad (2)$$

where Qwt = amount of waste generated by tourists; Itwg = tourist waste generation rate (kg/capita/day); Nt = number of tourists; Itwg = intermediate value compared to rural and urban areas provided in regional and local SWM plans (Florin, 2013). It should be noted that, in this study, Ilwg = 1 kg/guest/day.

4.1.3. Collected Samples' Composition and Experimental Quantification

The first sorting analysis was carried out during one week for each tourist destination (Gammarth and Hammamet), during both the winter and summer periods in Gammarth. The operation was limited to solid waste generated from hotels and quantities were provided by municipalities and the private sector. One percent (1%) of the waste generated from hotels per day (in February 2017) was sorted. This represents 150 kg in the case of Gammarth and 160 kg for Hammamet. Another sorting analysis was realised in August 2017 in Gammarth to compare the composition of the waste between the winter and summer periods.

Waste samples are fractionated before sorting with two sieve cuts, thus resulting in three screen fractions. The movement of waste is important to separate waste components from each other. The sieve cuts take place at 100 and 30 mm. Only the coarse fraction and the medium fraction (>100 mm and 100 mm to 30 mm) are fully sorted. From the fine fraction (<30 mm), only 10% are sorted.

The operations were conducted in covered and flat areas that belong to both municipalities. All necessary tools were available (screens, sorting table, equipment, scales, protective work clothing). Figure 4-1 shows the methodology of the elaboration of the sorting analysis.

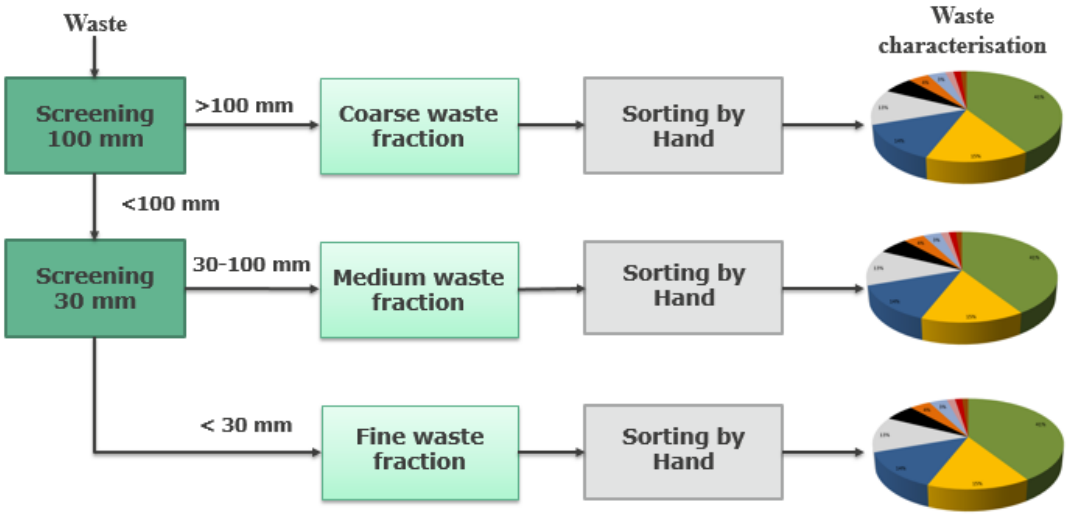

Figure 4-1. *Sorting analysis methodology*

Furthermore, the amount of waste generated by hotels in Hammamet was also estimated. The estimation method was executed in the field. In 2017, knowing the lack of means available to the municipality, the amount of waste collected from hotels was sorted and weighed during three days in each month. The average represents an estimation of the quantities of waste generated in a month.

The identification of the streams of solid waste generated by various hotel departments was realised for four hotels in Gammarth. All hotels' departments were visited to note the generated waste fractions in each of them and to identify those possibly responsible.

Regarding the characterisation of the waste generated in hotel kitchens, a sorting analysis was realised that involved the collection of food waste in three separate bins in four hotels in Gammarth: one bin for waste from food preparation and processing, one for waste from serving dishes, and one for waste from guests' plates. The workers in the kitchen represented the strong point during this operation. After sorting the total amount generated in the kitchen, a weighing step was required to calculate the percentage of each fraction.

4.2. RESULTS

Table 4-1 presents the indicators developed with regard to SWM in tourism zones, which are classified as follows:

Table 4-1. *Key indicators related to SWM in tourist destinations.*

Aspects	Indicators
Technical indicators	- General information about the destination (population, tourists per year, number of hotels, coastline length, etc.) - General information - hotels (no. of beds, rooms, occupancy rate, etc.) - Solid waste generation in hotels (ton/day) - Solid waste generation by tourists/guests (kg/day) and local citizens (kg/day) - Solid waste composition and characteristics (hotels and households) - Types of solid waste generated in different hotel departments - SWM practices in hotels (sorting, recycling, landfilling, etc.) - Sources and characteristics of solid waste from hotels' kitchens - Frequency of solid waste collection from hotels and households
Financial indicators	- SWM costs per hotel guest per night - SWM general costs paid by tourism establishments - Taxes paid by hotels for SWM - Solid waste collection costs (per ton) per tourism municipality - Solid waste cleaning costs (per year) - Adequacy of taxes paid for SWM
Organisational indicators	- Role of different actors in SWM in tourism areas - Percentage of tourist destinations covered by waste collection services - Types of solid waste collection services in tourism (public or private) - Number of collection/recycling facilities installed in the municipality - Beach cleaning in tourism destinations
Legal indicators	- SWM laws in tourist areas - National laws related to the environment - Requirements of the municipalities on SWM in hotels - MSWM plans and local objectives
Social indicators	- Hotels/employees' involvement in separation and recycling activities - Hotels' satisfaction (cleanliness of the destination) - Customers' satisfaction (cleanliness of the destination) - Responsibility of visitors and tourists in the assigned area

- **Technical indicators:** This box concerns general data related to tourism establishments, their classification and other information that concerns quantitative and qualitative indicators related to SWM operations (separation, collection, recycling, etc.);
- **Organisational indicators:** These indicators are mainly related to national and local SWM institutional frameworks, and to the structures and tasks of the different actors;
- **Financial indicators:** These are linked principally to the current financial framework, taxes paid by hotels, and whether these adequately cover municipal SWM costs;
- **Legal indicators:** These concern regulations and SWM laws at the national and local levels;
- **Social indicators:** These indicators concern the social issues related to SWM in hotels or in public areas (beaches, parks, streets, etc.) such as the motivation of the hotel team, the education of the staff, guest satisfaction, etc.

Based on the developed indicators, some were selected to report on the SWM situation in the tourism sector, especially for hotels in Tunisia.

4.2.1. Technical Indicators

4.2.1.1. Composition and characteristics of solid waste generated by hotels

This indicator should always be included in any decision-supporting process. It furthers the understanding of the characteristics of the waste generated and allows decision makers to define laws and actions to orient the campaigns to increase sensitivity, etc. The composition of solid waste from hotels is similar to that of household waste, but it varies somewhat depending on the services offered by the establishment. For example, those hotels that have restaurants have a higher share of organic waste (Styles, 2013).

Figure 4-2 presents the results of the waste sorting analysis on Gammarth and Hammamet, which aims to determine the amounts of different waste fractions generated by hotels.

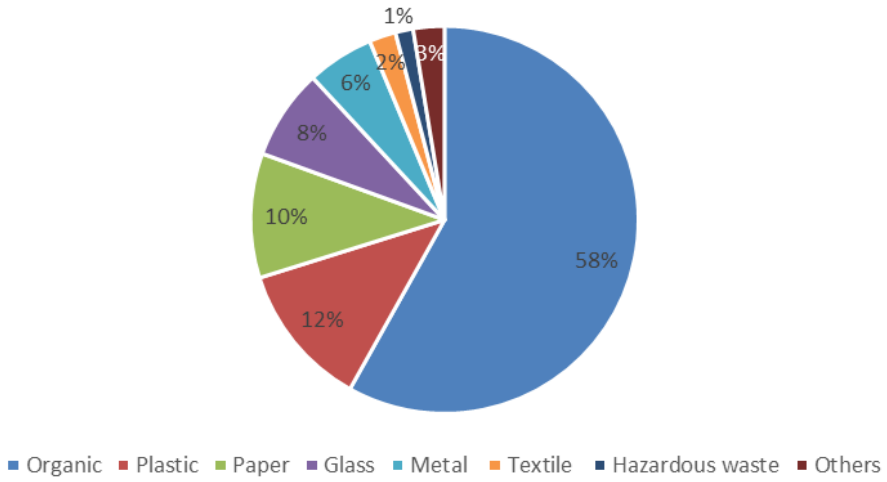

Figure 4-2. *Characteristics of the solid waste generated by hotels in Gammarth and Hammamet.*

The results indicate that a minimum of 36% of the waste generated by hotels could be valorised and recycled if proper sorting at the source in hotels was performed to separate glass, metal, and mainly plastics and papers. Moreover, the results indicate that bio-waste accounts for the highest percentage (58%), including kitchen waste and green waste.

The results of Figure 4-3 show that a higher level of organic waste was generated during the summer period and only small differences were observed for the other fractions. These differences correlate with the findings of Gidarakos et al. (2006), who reveal that municipal waste generation and composition depends on the flow of tourists throughout the year.

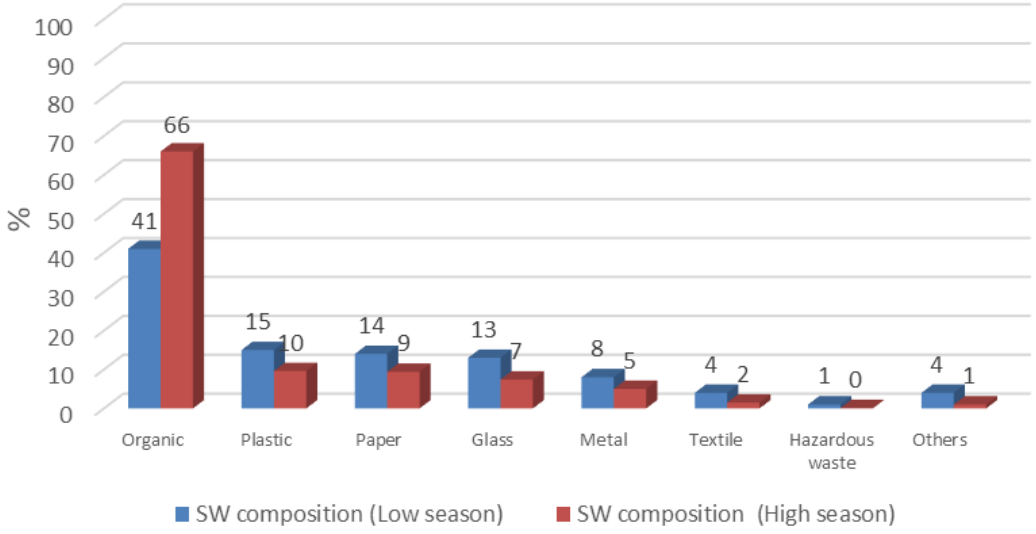

Figure 4-3. *Solid waste characteristics comparison in Gammarth between low and high seasons*

4.2.1.2. COMPARISON BETWEEN WASTE GENERATED BY HOUSEHOLDS AND HOTELS IN TOURISM AREAS

In order to identify the difference in term of characteristics of waste generated from households and from tourism accommodation establishments, a detailed sorting analysis was elaborated in Hammamet from 28.03.2019 to 10.06.2019. The sorting focused on 1% of the waste generated in Hammamet (hotels or households) in order to identify the present fraction (15 super fractions and 33 sub-category), as presented in Table 4-2.

These results confirm the outcomes of the characterisation illustrated in Figure 4-2, indicating that organic waste dominates hotels' waste with 55% of the total composition, of which 52% was vegetable foods. This was the same for households' organic waste (67% of total waste), of which 65% was vegetable foods. This fraction was followed by paper and cardboard and plastic (17% - 14% for hotels' waste, 6% - 10% for households' waste), which represent also an important recyclable fraction.

Table 4-2. *Sorting analyses of solid waste generated from hotels and households in Hammamet municipality.*

Material fraction	Material fraction	Examples	%	Waste from hotels	%	Waste from households
1. Organic waste	1.1. Vegetable food	Fruits, vegetables	52.5	55	65	67
	1.2. Animal based food	Meat products	0.5		2	
	1.3. Other organic waste	Lawn cuttings, tree cuttings	2		0	
2. Paper and cardboard and paper compound	2.1. Paper packaging and small cardboard boxes	Cardboard boxes of food, shoes, electrical appliances	2.5	17	0.8	6
	2.2. Cardboard boxes - transport packaging	Large cardboard boxes, which are usually not used in the household, but in trade, commerce or industry	0.5		0.2	
	2.3. Paper compounds for food with direct contact with the contents, but not liquids	Plastic coated cartons such as freezer packaging for spinach, pizza boxes and composite cans	0.8		0	
	2.4. Carton packages for liquid food	Tetra Pak, e.g., for milk, juice, tomato purée, cream	1.2		1.3	
	2.5. Other paper waste without packaging	Paper tissues, magazines, booklets, sheets	12		3.7	
3. Glass	3.1. Glass packaging	Beverage bottles, cans	1.8	2	0.6	1
	3.2. Other glass items (without packaging)	Breakage of window glasses, vases	0.2		0.4	
4. Plastic	4.1. Films< DIN A 4	Films from households for food	1.5	14	0.5	10
	4.2. Films> DIN A 4	Films from garden markets, agriculture	1		0	
	4.3. Plastic bags and carrier bags	Plastic bags (fruits, vegetables, meat), plastic carrier bags	2		4.0	
	4.4. PET beverage bottles	Bottles for water and soft drinks	7.8		3	
	4.4. Other bottles (without PET beverage bottles)	Bottles for shower gel, shampoo, cleaning agents	0.6		1	
	4.5. Other plastic packaging (without films, bags/bottles)	Yogurt cups, margarine cups, sausage packages, bowls for fruit or vegetables	0.6		0.5	
	4.6. Other plastic	Children's toys, bottle tops, shoes	0.5		1	
5. WEEE	5.1. WEEE	Electrical and electronic waste	0	0	0	0

Material fraction	Material fraction	Examples	%	Waste from hotels	%	Waste from households
6. Tinplate and tinplate compounds	6.1. Tinplate beverage cans (top cover aluminium)	Cans	0.1	2	0.2	1
	6.2. Tin cans	Cans for vegetables, processed tomatoes	1.8		0.8	
	6.3. Other tinplate packaging	Cans for hair spray, deodorant spray, closures of bottles	0.1		0	
7. Aluminium and aluminium compounds	7.1. Beverage cans made of aluminium	Cans (Cola, Pepsi)	0.3	1	0.5	1
	7.2. Other cans made of aluminium	Spray cans, food cans	0.1		0	
	7.3. Other packaging mainly consisting of aluminium or having aluminium proportions	Coffee bags, coated bowls for pet foods, toothpaste tubes of plastic covered inside with aluminium, bottle tops	0.2		0.3	
	7.4. Other aluminium objects items packaging	Household goods	0.4		0.2	
8.Other metals	Other metals without packaging	All kinds of scrap	0	0	0	0
9.Textiles	Textiles	Clothing and household textiles	1	1	2	2
10.Batteries	Batteries	Batteries from all areas of application	0	0	0	0
11.Hazardous waste	Hazardous material	All hazardous material without batteries	0	0	0	0
12. Mineral waste	Other mineral waste	Stones, rubble	0	0	0	0
13. Fine waste	Fine waste	Waste <30 mm	5	5	5	5
14.Undefined waste	Undefined waste	All wastes not listed under items 1 to 15	3	3	7	7
15.Wood	Wood	Wood	0	0	0	0

The outcomes of the sorting analyses shows that hotels generates large amounts of recyclable materials generated from specific departments, and that could be separated at source. In order to identify the advantages of the separate collection of waste fractions, a calculation of the benefits of paper and cardboard collection and recycling in Hammamet was conducted. This calculation was based on the quantities of total waste and the percentage of paper and cardboard in Hammamet from hotels and households (Table 4-3). The benefits of the sorted collection are possible on several levels:

- Informal sector and first waste collectors;
- Second level collection companies;
- Recycling companies;
- Waste collection and treatment cost saving.

In this calculation, the current paper and cardboard price was considered: 140 TND per ton for selling by the first collector, and 190 TND per ton by the second collector to recycling companies. The cost of collection and treatment was estimated at 70 TND per ton.

Table 4-3. *Calculation of the financial benefits and costs saving from paper and cardboard separate collection for the case of Hammamet.*

Waste generator	Percentage of paper %	Quantities (ton)	Revenues of collectors (TND)	Revenues of 2nd level collectors (TND)	Collection & treatment costs saving (TND)
Hotels	15.8	2,180	305,312	109,04	- 152,656
Households	4.7	1,156	161,938	57,83	- 80,969

Table 4-3 indicate that paper and cardboard sorting can bring benefits to collection companies and recycling enterprises as well. This can save collection and landfilling costs paid by the municipality and by ANGED, through the eco-tax fund.

4.2.1.3. STREAMS OF SOLID WASTE GENERATED PER HOTEL DEPARTMENT

Waste mapping is a methodology that allows hotels to identify the sources, types and quantities of waste they produce. The mapping approach allows to investigate where and how waste is produced, and present this visually in a way that can help to identify hidden costs of waste (purchasing costs, staff time, etc.). The process helps also hospitality establishments to prioritise areas where actions can be taken to minimise waste, reduce costs and achieve a sustainable SWM (Pirani & Arafat, 2014).

Solid waste is generated from different hotel departments such as guest rooms, kitchens, gardens, restaurants, administration, etc. This indicator allows the investigation of where and how waste arises. Table 4-4 presents the sources of different types of waste generated in different hotel departments in 36 hotels in Tunisia (Annex I.4). Those responsible (hotel, guest) for the different types of waste have been identified.

Table 4-4. *Principal types of waste generated from hotels' departments in Tunisia*

Department/zone of the hotel	Types of waste	Responsible	
		Guest	Hotel
Beach	Paper, plastic, cartons	100%	0%
Wellness area	Wipes, diapers, waste resulting from personal hygiene (bathroom kit, soap remainders)	100%	0%
Outdoor area (park, pool, garden, golf course)	Garden waste, paper, plastic	10%	90%
Kitchen	Food preparation waste, carton packaging, metal packaging, paper, textiles	0%	100%
Local restaurant and bar	Meal remains (bio-waste), glass, plastic and metal packaging	95%	5%
Laundry service	Tablecloths, towels, clothes, rags	0%	100%
Furniture and stock	Plastics, paper, cardboard	0%	100%
Maintenance service	Paint remains, cans, light bulbs, paper, plastic	0%	100%
Offices and administrative activities	Cardboard packaging, plastic bottles, glass, paper, ink cartridges, batteries	0%	100%
Conference rooms	Paper, plastic, meal remains, glass	90%	10%
Lifts and stairs	Paper, plastic	100%	0%
Guest rooms	Metal, plastic and glass packaging (minibar), paper and newspapers, plastic cups, wipes, personal hygiene waste (toilet bag, soap remainders), courtesy waste (slippers, shower cap, disposable products), batteries, medical waste	100%	0%

It should be noted that other types of waste are generated occasionally from the hotels' samples, and which having mainly hotels as a source:

- Bulky waste (supply, chairs, desks, sofas, etc.);
- Demolition and renovation waste (concrete, stone, brick, plaster, glass wool, ceramics, glass, treated wood, pipes, etc.);
- Hazardous waste (used electrical and electronic equipment, fluorescent lamps, batteries, discarded refrigeration equipment such as refrigerators, freezers).

4.2.1.4. SOLID WASTE ATTRIBUTABLE TO TOURISM (TON/MONTH)

Tourist zones generate different amounts of waste given the difference in terms of the number of hotels and number of tourists and visitors (Florin, 2013). The presented methodology refers to the waste generated by tourists at the hotel. The variables of Nn, Na, and Nt were collected based on the statistics of the Ministry of Tourism. The formula was used to estimate and compare the waste generated in Tunisia (tons/months) for the years 2010, 2012, 2015, and 2016 (See Figure 4-4).

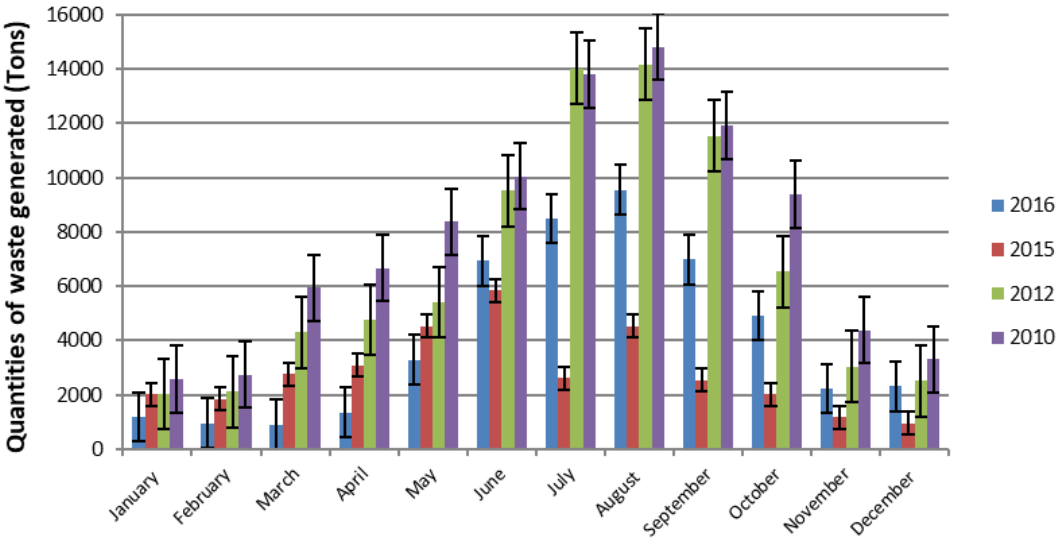

Figure 4-4. *Solid waste generation from accommodation establishments between 2010 and 2016 in Tunisia.*

Figure 4-4 illustrate a progressive increase in generated waste from hotels during the summer period, with a peak during July and August. The quantity decreased during the years 2015 and 2016, as a result of the significant decrease in the number of tourists following the terrorist attacks of Bardo and Sousse.

In addition, Figure 4-5 shows the increase in the quantities of waste generated in hotels in Hammamet during the summer period in 2017. This period began with an increase in May, and peaked during June, July and August (between 2,500 tons and 3,000 tons).

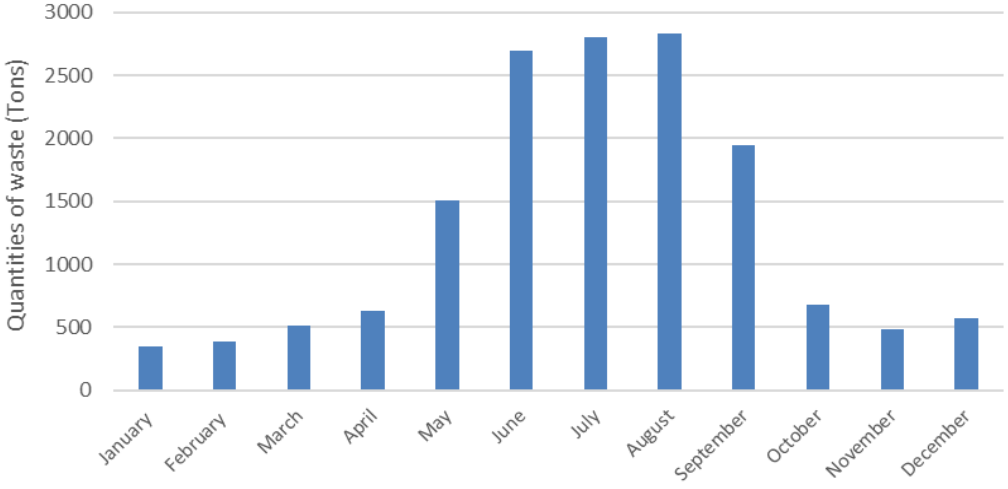

Figure 4-5. *Evolution of waste attributable to tourism in Hammamet in 2017 (ton/month)*

Taking into account the results of the estimation, and to understand the role of tourism in solid waste generation in Hammamet, a comparison with household waste generation was performed. Table 4-5 presents the detailed figures related to the

generated waste from hotels in Hammamet compared to the generated waste from households during 2017.

Table 4-5. *Solid waste generated from hotels and households in Hammamet.*

Month	Generated waste from hotels in Hammamet in 2017 (tons/month)	Total quantities of waste generated in Hammamet in 2017 (ton/month)	Hotels contributions (%)
January	348	2,229	15.6
February	390	2,191	17.8
March	516	2,772	18.6
April	629	2,625	24.0
May	774	2,803	27.6
June	2,700	3,186 (+Undefined quantity)	-
July	2,800	5,160	54.3
August	2,830	5,711	49.6
September	768	3,707	20.7
October	676	2,995	22.6
November	478	2,356	20.3
December	572	2,356	24.3
Total	13,480	38,091	35.4

The contribution of hotels was higher during July and August, representing 54.3% and 49.6%, respectively, of the total waste generated in the municipality.

Figure 4-6 presents the contribution of the hotels in Hammamet to the total quantities generated. The estimated amount of waste generated by hotels in Hammamet, in 2017, was as much as 13,480 tons, which represents 35.4% of the total waste generated for the year (38,091 tons).

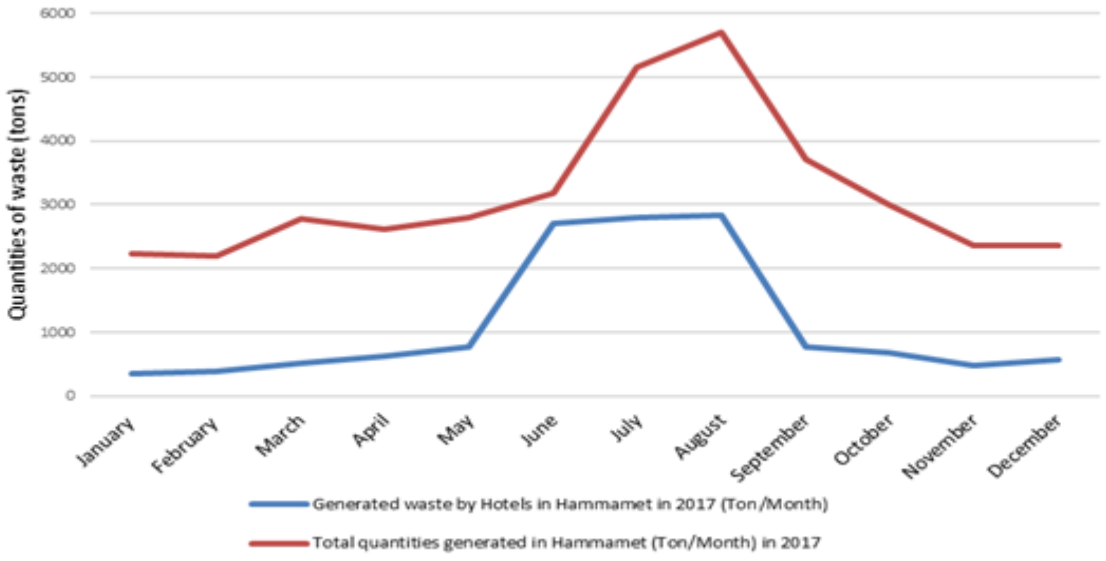

Figure 4-6. *Comparison of waste generated in Hammamet by tourism and households in 2017 (ton/month).*

4.2.1.5. SOLID WASTE GENERATED PER GUEST (KG/NIGHT)

The total quantity of waste generated per guest/night is the most appropriate indicator of the intensity of waste generation. For example, the waste generated from hotels on Djerba Island was estimated to be 2.8 kg/night (Ghribi, 2012). This indicator was measured in both Gammarth and Hammamet tourism destinations based on the generated quantities from hotels per day, the number of residents and the occupation rate in the hotels.
The results presented in Table 4-6 and in Table 4-7 indicate that the average waste generated per guest per day in Gammarth was 2.5 kg/guest/day; however, the average in Hammamet was 2.6 kg/guest/day.

Table 4-6. *Waste production per guest/night in hotels in Gammarth.*

Hotels	Number of residents	Number of rooms	Number of beds	Waste generated in hotels (Kg/day)	Waste production (guest/night)
Hotel 1	310	305	450	714	2.3
Hotel 2	83	119	283	496	6.0
Hotel 3	1,441	420	557	1,000	0.7
Hotel 4	535	86	150	679	1.2

Table 4-7. *Waste production per guest/night in hotels in Hammamet.*

Hotels	Number of residents	Number of rooms	Number of beds	Waste generated in hotels (Kg/day)	Waste production (guest/night)
Hotel 1	400	408	560	915	2.3
Hotel 2	305	214	345	560	1.8
Hotel 3	290	336	498	635	2.2
Hotel 4	200	115	210	812	4

4.2.1.6. COMPARISON BETWEEN WASTE GENERATED IN HOTELS (KG/GUEST/NIGHT) AND IN HOUSEHOLDS (KG/INHABITANT)

Waste generation varies as a result of affluence; however, regional and national variations can be significant, as can generation rates within the same city (Daniel & Perinaz, 2012).

Table 4-8. *Waste production per guest/night in hotels in different tourism destinations.*

Zone	Waste generated in hotels (kg/guest/night)	Waste generated in households (kg/inhabitant/night)
Hammamet	2.6 (2018)	1.0 (municipality of Hammamet)
Gammarth	2.5 (2018)	1.1 (Source: PCGD)
Djerba	2.8 (Ghribi, 2013)	0.8 (ACR+, 2016)

Table 4-8 shows that waste generated by hotel guests per night (average of 2.6 kg) is superior to the waste generated per inhabitant, per household, per night (average of 1 kg) in tourism municipalities in Tunisia.

4.2.1.7. SWM PRACTICES IN HOTELS

Waste generated by hotels can be treated in different ways. In Tunisia, hotels themselves actually decide on their SWM strategies, since laws are not sufficiently enforced by municipalities. Based on the questionnaire undertaken by 36 hotels in Tunisia, the results in Figure 4-7 indicate that 83% of hotels generate mixed waste to be landfilled, whereas only 17% of hotels are developing small recycling and composting initiatives. At that level, recycling means sorting different materials at the source (plastic PET, PEHD, paper and cardboard, glass, bread). On the other hand, the option of energy recovery is not currently on the table.

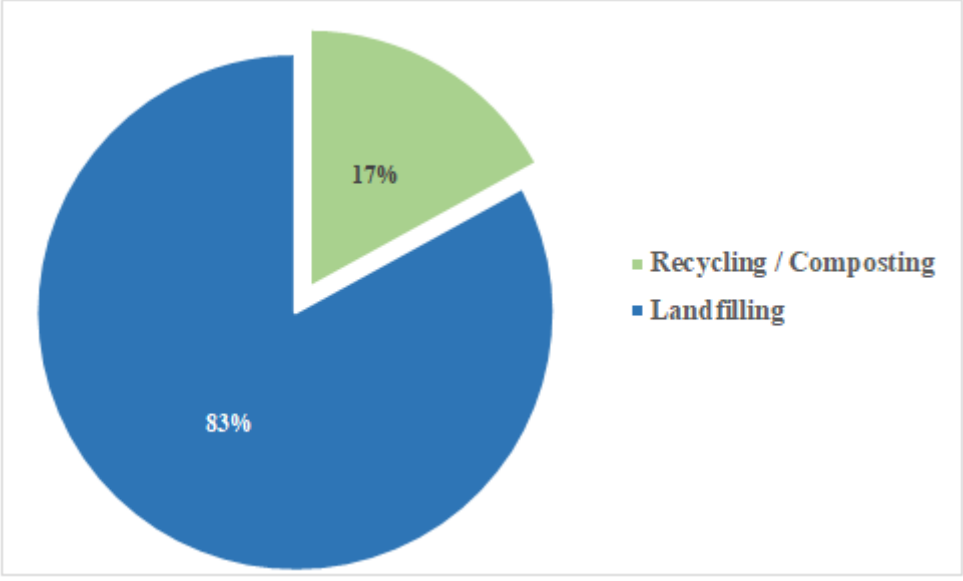

Figure 4-7. *SWM practices in hotels*

In the case of mixed waste generation, the municipality is responsible for collection and transportation. This collection does not include hazardous waste, green waste, electronic waste, chemical waste, and so on (see Figure 4-8). In this case, waste pickers collect the recyclable materials from the landfills to be sold and recycled.

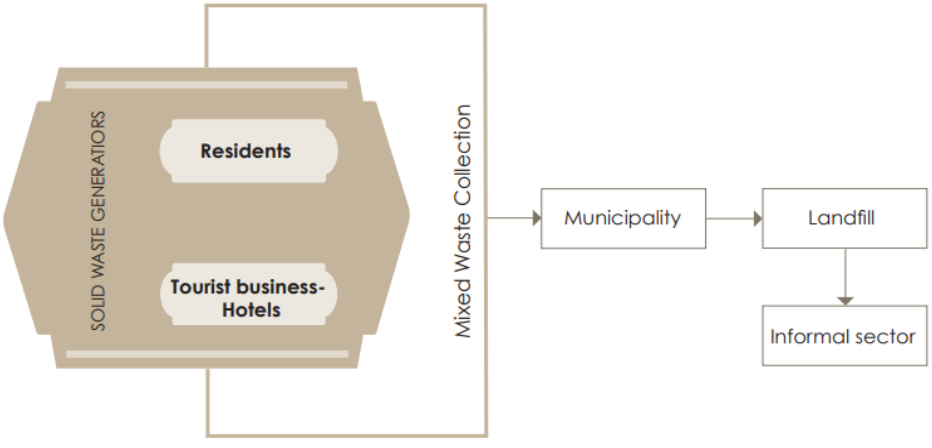

Figure 4-8. *Case of mixed waste generation in hotels in Tunisia.*

In the case where hotels sort their waste, two types of waste are eliminated: mixed waste (collected by the municipality) and recyclable waste such as paper, cardboard, plastics, metals and glass, which are collected by private companies and informal collectors (see Figure 4-9).

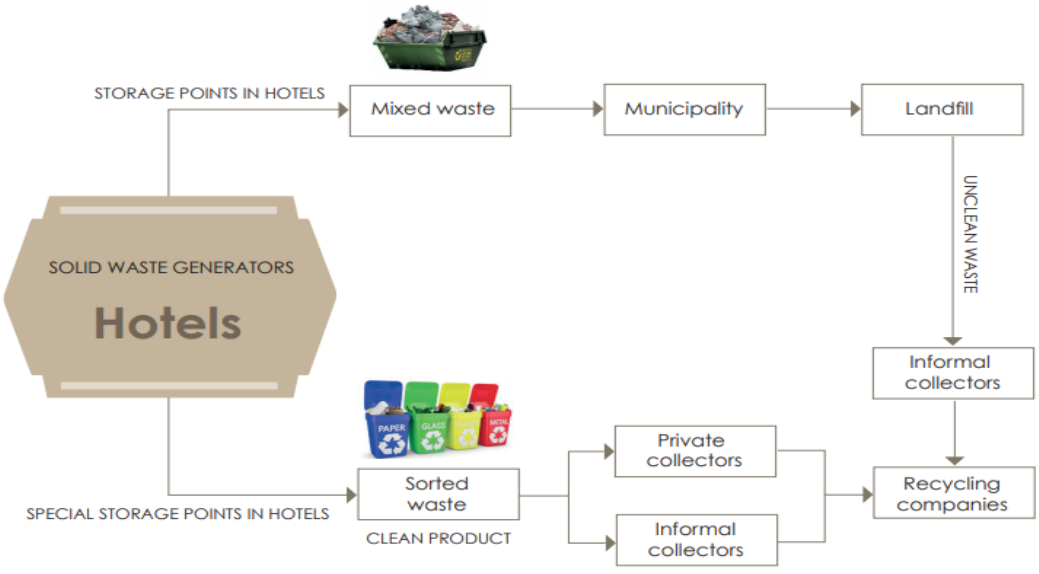

Figure 4-9. *Case of solid waste sorting at the source in hotels in Tunisia.*

4.2.1.8. SOURCES AND CHARACTERISTICS OF SOLID WASTE GENERATED FROM HOTELS' KITCHENS

Food waste is defined as "any by-product or waste product from the production, processing, distribution, and consumption of food" (Okazaki et al., 2008). In hotel kitchens, food waste can be the result of the preparation of food, its processing, from serving dishes or from the guests' plates (Pirani & Arafat, 2016).

In this research, it was found that about 39% of the waste was from food preparation, 59% from guests' plates, and 2% from non-consumed food. On the other hand, the characterisation of the kitchen waste in these establishments showed that 83% of the generated waste was bio-waste. The remaining 17% included paper (6%), plastic (5%), glass (3%) and metal (3%). In fact, all fractions were mixed with other types of waste from other departments. This indicator could help hotels to identify possible actions to minimise the generated food waste. Figure 4-10 illustrate the composition of waste generated in the kitchen, the source being the preparation of food, dish cleaning and returned and non-consumed food (Annex I.5).

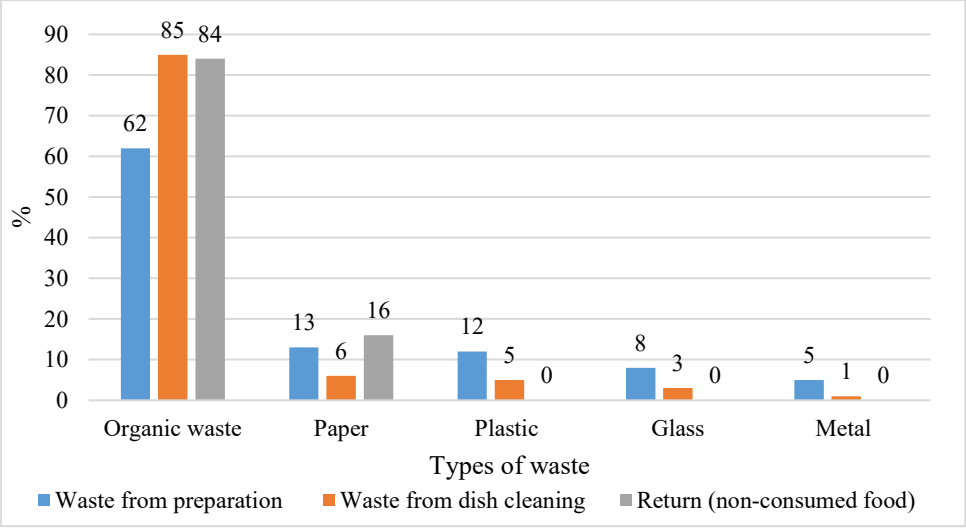

Figure 4-10. *Waste generated in four hotels' kitchens in Gammarth*

4.6.1. ORGANISATIONAL INDICATORS

4.2.2.1. SWM ACTORS AND RESPONSIBILITIES

In Tunisia, several actors take part in SWM in tourist areas. The municipality, the private sector, tourist businesses including hotels, the MLAE, the Ministry of Tourism and the Ministry of Finance are the main active stakeholders in this process. Table 4-9 presents the classification of their responsibilities.

Table 4-9. *Role of different SWM stakeholders in tourist destinations in Tunisia.*

Institution	Role
Municipalities	- Waste collection and transfer - Cleaning the streets and beaches - Solid waste collection infrastructure
Hotels	- Solid waste storage and preparation for collection - Responsibility for cleaning the surrounding beaches and supporting the efforts of the municipality
MLAE	- Special cleaning actions - Planning and coordination of cleaning actions
Ministry of Tourism	- Support for special cleaning actions - Discussing with municipalities and the MLAE about the plan of the Tourist Destinations Protection Fund
Private sector (collectors and recyclers)	- Participation in collection and cleaning efforts - Recycling activities
Coastal Protection and Development Agency (APAL)/ ANGED	- Organising special cleaning actions

These actors engage in SWM without any special strategy, which results in large quantities of waste generated during the summer period from tourist establishments. It should also be noted that no programme for sorting at the source for hotels, nor for the recycling of waste, is scheduled by the authorities at the moment.

4.2.2.2. SOLID WASTE COLLECTION SERVICES

In Tunisia, municipalities are responsible for solid waste collection, and they can also delegate this task to the private sector. One hundred percent of tourism zones are covered by a collection system, but the quality of the service differs from one area to another. Municipalities tend to privatise the collection of waste from hotels, given the low price and the quality of service. This sector is also involved in terms of mechanical or manual cleaning activities (streets, beaches, etc.) during the high seasons. Table 4-10 presents some examples of the service providers within four tourist municipalities.

Table 4-10. *Intervention of private and public sectors in waste management services.*

Tourist municipalities	**Public services (%)**	**Type of services**	**Private services (%)**	**Type of service**
Marsa-Gammarth	50%	Solid waste collection from households & hotels; street cleaning	50%	Solid waste collection from households & hotels; street & beach cleaning
Hammamet	25%		75%	
Sfax	70%		30%	
Bizerte	100%		0%	

4.2.2.3. COLLECTION AND RECYCLING FACILITIES IN TOURISM MUNICIPALITIES

Private collection and recycling facilities are important actors with regard to SWM in tourism. Their presence in tourist municipalities can open the doors to new waste sorting and recycling initiatives in hotels. Table 4-11 presents the existing companies in six tourist areas in Tunisia. They offer different services for several types of waste. The table (ANGED, 2018) also indicates the difference between existing aggregated companies (small companies for collection) and active companies.

The results appeared in Annex I.7 indicate that, 41% of the visited 19 tourism municipalities have composting experiences, from 200 kg per year up to 1,000 and 2,000 tons per year composting plant.

Table 4-11. *Existing collection and recycling companies in six tourist destinations.*

Tourist destination	**Collection companies**	**Recycling companies**
Tunis	37 (25 active)	15 (PET, film, sacs, membranes)
Nabeul/Hammamet	7 (4 active)	4 (PET, film, sacs, membranes)
Sfax	25 (15 active)	8 (PET, film, sacs, membranes)
Sousse	42 (30 active)	16 (PET, film, sacs, membranes)
Mounastir		6 (PET, film, sacs, membranes)
Mahdia		2 (PET, film, sacs, membranes)

4.2.2.4. BEACH CLEANING SERVICES IN TOURISM DESTINATIONS

The cleanliness of beaches is the first impression tourists and visitors get when they visit a coastal tourism country. By establishing a high quality-cleaning programme, municipalities can ensure a clean and sustainable area, and guarantee that visitors will revisit the destination.

The Tunisian coastline is 1,188 km long, of which 575 km are sandy beaches, which accounts for 49 touristic beaches and 71 public beaches. Table 4-12 shows that in Tunisia, beach cleaning is either performed by tourism municipalities or private companies, and sometimes with the support of APAL, especially during high seasons. It also indicates that in most municipalities, the frequency of beach cleaning services increases during the summer compared to the winter season, despite the existence of tourists and visitors (particularly national visitors) in this period. The table also confirms that in most cases, the mechanical cleaning actions are the responsibility of APAL, which is equipped with the required machines.

Table 4-12. *Beach cleaning organisation in tourism municipalities in Tunisia.*

Municipality	**Cleaning action on beaches**	**Beach cleaning responsibility**	**Beach cleaning manually/mechanically**
Djerba HS	Monthly/daily during the summer	Municipality and APAL	APAL: Mechanically Municipality : Manually
Djerba Midoun	Monthly/daily during the summer	Municipality and APAL	APAL: Mechanically /Municipality : Manually
Bizerte	Seasonal/daily during the summer	Municipality and APAL	Both
Hammam Sousse	Every week winter/daily summer	Municipality and APAL	Both
Sousse	Daily	Municipality and private sector	Both
Hammamet	Seasonal/daily from May	Private sector and APAL	Both

In 2019, APAL fixed 2.3 million dinars to the cleaning of only 140 km periodically to reinforce the efforts of the municipalities during the summer period.

4.6.2. FINANCIAL INDICATORS

4.2.3.1. TAXES PAID BY HOTELS FOR SOLID WASTE COLLECTION

In Tunisia, hotels pay taxes for general services, including SWM. These taxes amount to 2% of their annual turnover: 1% for the municipality and 1% for the fund for the protection of tourist destinations (the allocated budget is decided after discussion with the tourism authorities). Activities are related to solid waste collection and transfer, road sweeping, beach cleaning, etc. (see Figure 4-11). It should also be noted that the fund, financed by hotels, is also used to finance other activities, such as security in tourist areas.

Municipalities say that the aid received from the fund is not sufficient, and does not cover the costs of waste management, especially for large tourist municipalities.

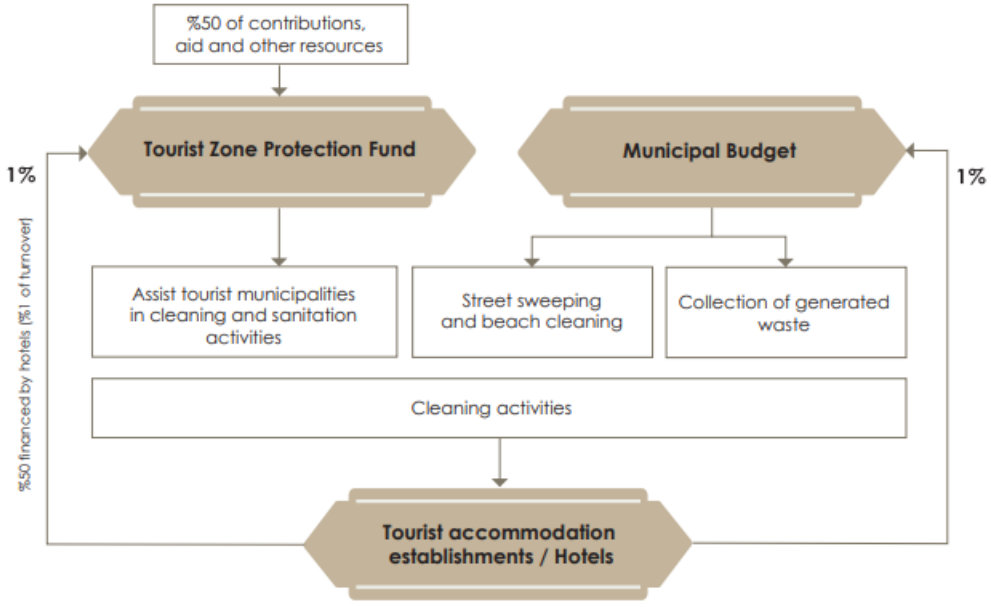

Figure 4-11. *Financial system of SWM in tourism zones in Tunisia.*

4.2.3.2. SOLID WASTE COLLECTION COSTS

The collection process is a high priority in the management of solid waste in tourist areas. This operation has a direct impact on the cleanliness of the destination. It may be ensured by the municipality or delegated to the private sector. Human resources, maintenance, fuel and other operations cost money. Data collected from private companies and municipalities allowed us to compare public and private sector costs in three tourist cities (La Marsa, Hammamet and Sfax), revealing that public costs are greater than those of the private sector (Figure 4-12).

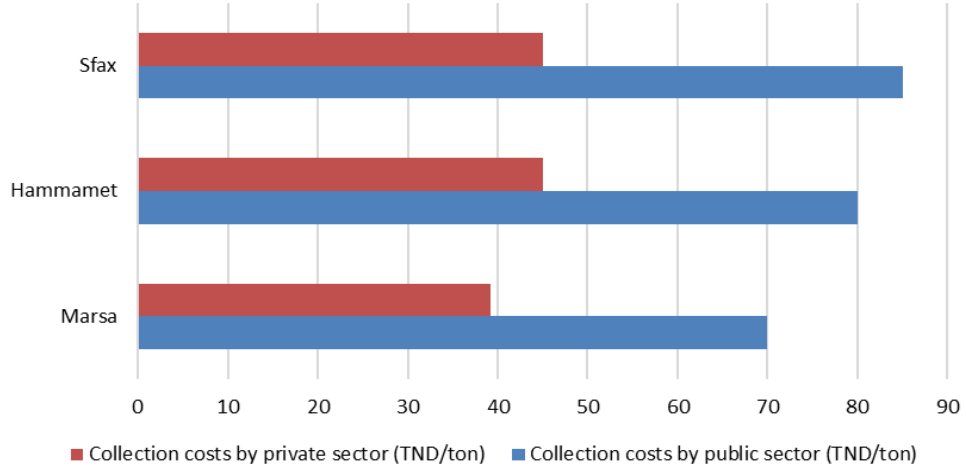

Figure 4-12. *Comparison between private and public solid waste collection costs.*

This difference is due to competition between local companies. On the other hand, the results of the questionnaire carried out by hotels indicated that 100% of the questioned municipalities are more satisfied with the private collection services since they are well equipped and better organised than the services provided by municipal authorities. This is especially the case with regard to big waste management companies.

4.2.3.3. ADEQUACY OF TAXES PAID BY HOTELS

With regard to SWM, hotels pay taxes for the provision of services, such as collection and transportation to landfills, which are provided by the municipality. Figure 4-13 provides a comparison between the taxes paid by four Tunisian hotels for general municipal services and the municipal costs for the collection of different mixed waste amounts.

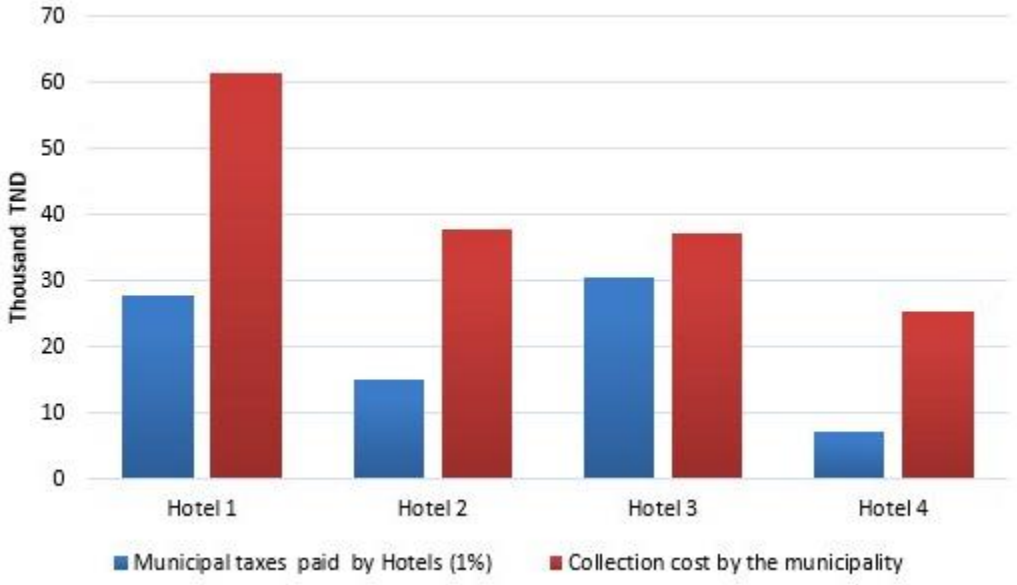

Figure 4-13. *Comparison of the taxes paid by hotels to municipalities (1%) and the municipal collection costs from hotels.*

4.6.3. SOCIAL INDICATORS

4.2.4.1. EMPLOYEE INVOLVEMENT IN SEPARATION AND RECYCLING ACTIVITIES

Hotel owners, managers and employees must make a commitment to SWM in their establishments, through waste reduction and sorting and recycling initiatives, if these programs are to be successful (Favro & Brebbia, 2013). Hotels' staff should be included at all stages of the programme so that they understand and support the SWM strategy in the hotel. The questionnaire results show that 70% of hotels do not have any apprenticeship programmes for staff to learn the appropriate collection/sorting of waste.

4.2.4.2. HOTEL AND CUSTOMER SATISFACTION

A questionnaire was undertaken in six tourist areas (Hammamet, Sfax, La Marsa-Gammarth, Sousse, Mahdia and Djerba) with 50 hotel guests of different nationalities from Europe, America, Africa and Asia (see questions in Table 4-13).

Table 4-13. *Interview for hotel guests.*

Questions	Number and categories of questioned guests
Are you interested in the issues of "waste management" and "cleanliness" in tourist destinations?	50 guests: 30 guests (20-40 years old) and 20 guests (40-60 years old) from Europe, America, Africa and Asia
What do you think of the cleanliness/hygiene/quality of the hotel?	
How do you evaluate cleanliness around the hotel?	
Do you think that the number of garbage cans around the hotel is sufficient?	
What do you think of the cleanliness in the tourist area generally?	

The questionnaire results showed that all guests were interested in a clean destination, and were also satisfied with the cleanliness and the hygiene of the hotel. However, 90% of the guests were somewhat dissatisfied about the cleanliness of the streets around the hotel and 50% were unhappy about the cleanliness of the tourist area generally. All guests who completed the questionnaire complained about the lack and/or insufficiency of bins. On the other hand, we asked the hotels responsible in a separate questionnaire about their opinion regarding the cleanliness of the tourism destination. Eighty-eight percent of the hotels were not satisfied with the cleanliness of either the tourist area or the locality of the hotel, or of the beaches.

4.7. DISCUSSION

These results agree with the findings of Chapelle and Gouin (2015) that tourism structures produce different waste types, which mainly belong to the categories of organic waste, cardboard, paper, glass, tin, plastic and packaging. The indicator, which aims to identify the sources of waste by department and manager, shows that the hotel and the visitor are both responsible for the generation of waste. As can be seen in Table 4-4, organic waste is generated mainly in the kitchen and restaurant, and other types of waste are generated from different departments unequally.

In the tourism sector in Tunisia, organic waste represents the main generated fraction, which is similar to the case of Vietnam (Phu et al., 2018), and its percentage depends on many parameters such as the type of tourism and the season. To confirm this, the results of this study show a difference in the composition of the waste between two seasons in Gammarth. This could be the result of a change in terms of the type of tourism (more beach tourism than business tourism during the summer) and, consequently, a change in the type of service provided in the hotel restaurants, such as more buffet service in restaurants, which generates more food waste (Hackes et al., 1997). Furthermore, this study found that 83% of the generated kitchen waste was bio-waste. It was sourced mainly from guests' plates, food preparation and non-consumed food. The large amount of

organic waste present in hotel solid waste has the potential to cause environmental problems; at the same time, it has great potential for resource recovery through compost production. Given these points, it is recommended that hotels use an 'A la carte' service rather than a buffet in their restaurants, which could reduce waste from guests' plates (Pirani & Arafat, 2016).

On the other hand, the calculation of the quantities of waste generated represents an important indicator to better plan the MSW collection, personnel and equipment utilization, etc. The results of the theoretical quantification of solid waste generation in Tunisia, shown in Figure 4-4, coincide with the case of the Galapagos Islands (Torretta & Salazar-Valenzuela, 2014); this indicates a strong seasonal pattern linked to tourism seasonality and reveals that solid waste generation has recorded peaks, especially for the years 2010 and 2012. The figure also shows a decrease in these quantities in 2015. This was due to the tourism crises in the country after the terrorist attacks at Bardo and Sousse. The practical quantification in Hammamet served to confirm the difference of the quantities generated between the seasons, which is due to the increase of the number of tourists and the reopening of closed hotels during the winter. This amount can reach more than half (54.3%) of the total generated waste in Hammamet, which confirmed the idea reported in Reference (DO, 2016). The increase in solid waste quantities during the summer season represents a problem for municipalities in terms of the availability of resources and the costs of collection. Furthermore, the study found that 83% of hotels generate mixed waste, without any sorting, which ends up in the landfill. In this case, only a portion of the unclean recyclable waste is recovered by waste pickers from the landfills.

Furthermore, the private sector should also contribute in this process. This study has shown that the costs of collection by the private sector are lower than those incurred by the municipality, with hotels being satisfied overall with the offered service. In the same way, the existence of collection and sorting companies of recyclable materials represents a motivation to launch sorting at source in hotels, since a potential of 36% of recyclable materials generated by hotels exists. Recyclable materials collected directly from hotels are clean and available to private collectors. The main barriers to collaboration in the form of 'collection companies/hotels' are related to the costs and the profitability of the operation. Some companies also require the payment of transportation costs to make the collection of recyclable materials profitable. However, some hotels consider it a resource and charge a fee for collecting it. Apart from that, and following our discussion with hotels and private collection companies, other points are taken into consideration when developing this collaboration such as types of materials accepted by the collector, materials' preparation requirements (clean sorted materials, clean commingled materials, etc.), the supply of collection containers by the collector, possibility of monitoring and documentation of the collected quality, etc. The local authority could also be included to organise this collaboration.

Undoubtedly, the development of the sector must be accompanied by the improvement of the financial framework for waste management in tourist destinations. Actually, Figure

4-13 shows that taxes paid by hotels do not cover the costs of collection and cleaning the streets and beaches. On another hand, the municipality pays more money by collecting increased quantities of waste from hotels. To address this, the creation of a specific tax for residual waste generated per ton is recommended. In this way, hotels will conduct appropriate and effective sorting to minimise the waste collected by the municipality. In addition, the local authority may charge additional fees on hotels to cover the costs of the collection operation.

From an institutional point of view, it should be stated that municipalities need specific organisational, technical and financial solutions to manage solid waste sustainably. For many reasons (financial, technological, know-how, etc.), municipalities cannot ensure that this task is carried out properly in such a way as to satisfy tourists. Hotels are not sufficiently experienced. Moreover, while local private collecting companies can do this work efficiently on a technical level, they are not able to ensure organisational decisions. The main actors of the tourism sector (Tunisian Federation of Hotels (FTH), the National Office of Tourism (ONTT), in cooperation with the municipalities and SWM authorities, must work together to provide a sustainable solution based on organisational issues, involving local businesses and experts. The sorting of the generated solid waste at the source is a solution that can reduce the quantities of waste to be landfilled and increase the availability of clean products for collection and recycling companies.

Among the identified social indicators, two were taken into account. They concern the satisfaction of the hotels' guests about the cleanliness and the involvement of the hotels' staff in waste management initiatives. Findings of these indicators indicate the dissatisfaction of guests and hotels' owners about the cleanliness around the hotel, as well as in the tourist destinations. They also show a weak integration of workers in the waste management operations. These results confirm the importance of the improvement of the SWM concept to improve the cleanliness of the tourist destinations. Moreover, the results stress the importance of the integration of the hotel through waste minimisation, waste sorting at source, beach cleaning, etc.

4.8. CONCLUSIONS

It has been increasingly expressed that solid waste represents a key concern in the hospitality industry and that city clean-ups are among the pressing elements of sustainable tourism (GIZ/SWEEP-Net, 2014). Improving the SWM system in tourist areas in Tunisia could, consequently, enhance the satisfaction of hotels and guests concerning the cleanliness of the tourism destination, as well as create a suitable environment for more tourist arrivals, thus strengthening the Tunisian economy.

This chapter revealed that Tunisian hotels generate large amounts of MSW, mainly during the summer period, which ends up as landfill. It contributes significantly to the total waste generated in the destination during the year, and especially during the high seasons. This is the case for hotels in Hammamet, which generate 35.4% of the total waste in the city, and which could reach 54.3% during July. In hotels, waste is produced from different

departments, and the responsibility for producing it is shared between guests and the enterprise. In addition, it can be concluded that the composition of the waste generated from hotels is dominated by the organic fraction (58%), which is similar to the composition of waste generated from households. Therefore, the separation at source in hotels would allow clean organic and recyclable materials to be obtained, which could then be composted and recycled.

The top-down waste hierarchy is difficult to apply directly to hotels. Actually, a bottom-up approach could be a solution for the case of Tunisia. Municipalities could temporarily continue the landfill operation, but this process should be accompanied by increasing financial pressure on hotels by charging taxes on residual waste collected.

This chapter also developed twenty-nine indicators covering technical, organisational, financial, legal and social factors. These indicators have the greatest influence on decision making. The employed indicators in our research were based concrete data, and are used to develop feasible and possible solutions for the case of tourism destinations in Tunisia.

This research has some limitations which have to be pointed out. In this study, the survey did not obtain the determined sample size because some hotels declined to answer the survey. Out of the 36 organisations who were selected for the sample, 27 respondents refused to participate in the study. Similarly, the difficulties encountered in collecting more information from the official level cannot be ignored; we succeeded to reach 19 tourism municipalities from 42, despite the support of the MLAE.

5. POSSIBLE CONCEPTS FOR THE IMPROVEMENT OF SOLID WASTE MANAGEMENT IN TOURISM AREAS IN TUNISIA

The need for sustainable MSW management is one of the most common questions, especially when there is a growing worry about the increasing generation of waste. A suitable approach in MSW should be an integrated approach that could deliver environmental, social and economic sustainability.

SWM in tourism destinations is defined by different activities associated with waste collection, transportation, treatment and cleaning. It concerns, at a first level, waste generated from households, hotels, restaurants, streets, old towns and beaches.

In this chapter, different organisational, financial and technical solutions are discussed to improve the SWM in tourism areas in Tunisia and to ensure sustainable tourism. These solutions are developed after diagnostics of the SWM situation in these areas; this is based upon analyses of the developed institutional, legal, financial, organisational and social indicators.

First, gleaned from the analyses of the current organisational situation of the SWM in tourism zones, some **organisational solutions** are developed; in particular, the involvement of all actors (national and local authorities, federation of hotels, hotels, private companies, NGOs, etc.) through the establishment of national-local, private-public partnerships, which aim to create the sustainable management of waste generated from tourism establishments, households, streets, beaches, etc.

The second solution concerns the optimisation of packaging recovery and recycling system (ECO-Lef) through the development of an EPR concept in Tunisia. **This solution is not only financial, but also organisational**; it is designed through the creation of an organisation managed by producers and fillers (to be called New System Operator NOS), which will play the role of a system operator. In this system, all producers, importers and fillers of goods are obliged to pay for the products they are putting on the national market. However, the operator will ensure the management of the packaging and must reach the collection and recycling goals fixed by the authority.

Finally, the composting of clean kitchen waste and green waste generated from tourism areas (from hotels, gardens, municipalities, etc.) represents one of the **technical solutions** that can contribute to saving collection, transport and landfilling costs. In addition, the produced quality compost could be used for private, municipal and agricultural activities. This solution should be supported by a law obliging big waste generators to sort their food waste at source. Furthermore, a communication plan should be established between the municipality, local citizens and tourism establishments to ensure an adequate collection of green waste generated.

In fact, the developed solutions are designed in total concertation with the national authorities, its orientations and planned projects, which aim to reduce the amounts of landfilled waste and to increase the recovery and the recycling of materials.

5.1. Organisational Solutions For Solid Waste Management in Tourism Areas

Sustainable tourism is a main focal point in the discussions on environmental integrated tourism development. However, existing research shows that sustainability is a complex concept that requires more critical analysis (Lu & Nepal, 2009). Tourism is considered an operator for socioeconomic development in many regions and areas, particularly in developing countries (Edmundo & Rodrigo, 2015). However, tourism has been recognised as a high energy and water resource demanding activity, which is also generating significant amounts of solid waste (Antonis et al., 2015). It is also recognised as a resource-intensive industry (Najdeska & Rakicevik, 2012).

The development of tourism, as one of the largest industries in the world, requires effective SWM measures (Dileep, 2007). The latter is considered the most significant environmental aspects related to tourism activities (Gruber et al., 2016), since the cleanliness of these destinations is an essential requirement to ensure sustainable tourism. Further, by means of exhaustive coverage and recycling of packaging, the appearance in tourism destinations, rural areas and beaches will be significantly improved (Glenn, 2001).

This criterion could have a positive impact on tourism and, thus, on the overall economic development in the country (Christer, 2003). However, the mismanagement of waste is considered the main factor contributing to the pollution of beaches, marine life and the ocean (Prabhakar et al., 2016). Many other factors could be also taken into consideration such as street litter, manufacturing sites, plastic processing and transport, etc. (Marine Litter Solutions, 2019). The image of a beach changes rapidly with the appearance of pollution or other marine debris, and travellers are not hesitant to change plans very rapidly (Tyrrell, 1992). This parameter plays particularly a critical role in travellers' decision criteria. Local recreation and tourism industries can suffer major economic consequences because of a damaged image (Arif et al., 2015; Tyrrell, 1992).

SWM is an important process and has major impacts on the development of a sustainable tourism model (Hoang, 2017). It is considered a complex process that involves the consideration of multiple and interconnected issues. The characteristics of solid waste in tourism destinations, and amounts generated during the year or on special seasons, makes the process even more complex. Therefore, in addressing SWM issues in tourism destinations, it is appropriate to use an integrated and sustainable approach that recognises the various stakeholders and clarifies the responsibility of each of them.

In tourism destinations, SWM services are provided for tourists and local citizens. In Tunisia, these services are provided either directly (by the municipality) or by contracting a private service-provider. SWM services are mainly related to the collection, transport and treatment of the generated waste. It tends to be considered an essential service to ensure a clean tourism area. In consequence, it also supports the economic and the social activities in tourism cities (En et al., 2017).

Therefore, the development of an innovative and participative approach that is able to accommodate local citizens, tourists and visitors' needs is required. In order to bring

SWM services into reality effectively and efficiently, cooperation between the government, local stakeholders and public service users in Tunisia is important.

5.1.1. METHODS AND FIELD WORK

In this section, a participative and descriptive approach was employed. First, to analyse the organisational and financial SWM concept in the tourism sector in Tunisia, data was collected through observations and analyses of documents. Accordingly, interviews and discussions were then held with key administrators and officers of 19 tourist municipalities, officers of central government agencies, private contractors and recyclers, local citizens and tourists. Data was also obtained from official documents, reports and forms pertaining to this research. The purposes of the first part of the paper are to analyse and describe the SWM processes and the role of different actors in ensuring clean tourism destinations in Tunisia. Based upon the results, possible improvement scenarios were developed.

5.1.2. RESULTS

5.1.2.1. DIAGNOSIS OF THE CURRENT ORGANISATIONAL STATE

SWM in tourist destinations has its own role. This process is more complex as local authorities have primary responsibility for effectively managing large amounts of waste to satisfy local citizens, visitors and international tourists. The collection process is a high priority in the management of solid waste in tourism areas and has a direct effect on the cleanliness of the destination. In tourist destinations, SWM encompasses waste collection from streets, households and tourism establishments (hotels, restaurants, and so on), the cleaning of the streets and roads, cleaning of beaches, communication with waste generators, etc.

In Tunisia, MSW refers to the waste collected by the local government (municipalities) and includes household, commercial and industrial solid waste, street sweeping and beach cleaning. These efforts are supported by central government, which ensures special cleaning actions take place during the year (with the support of APAL), especially during the summer period, to provide a clean destination and beaches for tourists and visitors. Figure 5-1 illustrates the current general organisational scheme of the SWM in tourist areas in Tunisia.

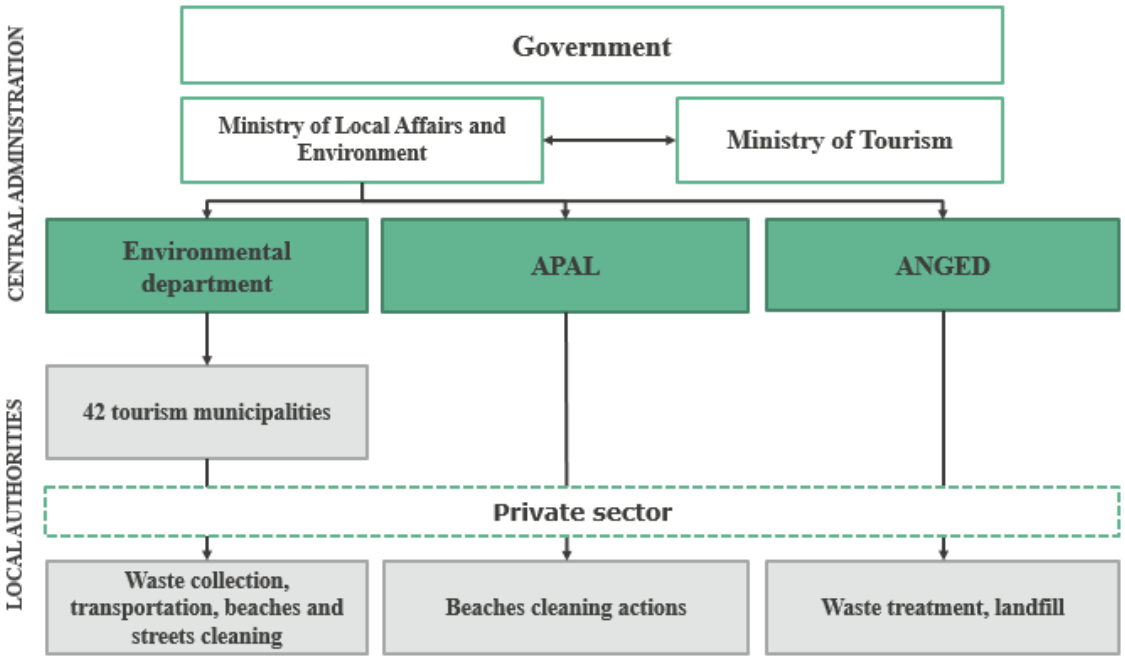

Figure 5-1. *Institutional framework of SWM in tourism in Tunisia*

Overall, hotels pay general taxes on 2% of their turnover; 1% for the municipality budget and 1% to the tourism protection fund. According to Figure 4-13, this contribution is considered insufficient as it does not cover the SWM costs paid by the municipality.

In addition, the number of hotels that participate in sorting their waste at source is inadequate (only 17% of the hotels questioned in Tunisia contribute with small and inefficient sorting and composting programmes) despite the existence of a large potentially recyclable fraction in the generated waste.

Moreover, with the exception of some pilot tests, no sorting at source in households exists in the country. This places even more financial stress on the municipality, which suffers from several technical, financial and organisational problems that present obstacles to the appropriate management of solid waste. These problems become more complex during the summer as the return of local citizens living abroad increases the quantities of waste generated.

5.1.2.2. STAKEHOLDERS' RESPONSIBILITIES

Stakeholders represent the actors who participate in a decision-making process, including those affected by a decision and those well-informed about the topic (Ernest, 1986). Solid waste management stakeholders are individuals or groups that have specific concerns and roles to play in the subject of managing solid waste.

In Tunisia, several actors participate in SWM in tourism areas. The main stakeholders in this process are mainly the municipality, the private sector, tourism businesses including hotels and restaurants, MLAE, ANGED, the Ministry of Tourism, and the Ministry of Finance, all with differing degrees of intervention. Table 5-1 details their separate responsibilities and characteristics.

Table 5-1. Results of the analysis of the different stakeholders' responsibilities.

Partners	Tasks and responsibilities	Characteristics
Municipalities	- Waste collection and transportation - Cleaning the street and beach - Development of solid waste collection infrastructure	- Limited resources and know-how - Bureaucracy - Starting the decentralisation process - Lack of data about the sector
Hotels	- Solid waste storage and preparation for collection - Cleaning the surrounding beaches and supporting the efforts of the municipality (not regularly) - Paying taxes (2% of turnover) for different services	- Limitation of know-how related to SWM and sorting - In some cases, lack of financial resources (small businesses) - Motivated to have labels, particularly chain hotels
MLAE	- Planning and coordination of special cleaning actions - Development of national strategies	- SWM strategy to be clarified - Limitation of resources
Ministry of Tourism	- Support for cleaning actions - Discussing with municipalities and the MLAE the action plan of the "Tourist Destinations Protection Fund"	- No direct intervention in the SWM field - No experience in the SWM sector
Private sector (collectors and recyclers)	- Participation in collection and cleaning efforts - Sorting and recycling activities	- Lack of private sorting and recycling companies - Lack of available recyclable quantities
APAL & ANGED	- Organising special cleaning actions	- In charge of many other activities - Lack of logistical means
Community and civil society	- Special clean-up actions organised by NGOs and local organisations	- May lack resources, expertise, motivation and organisation - Often unwilling to pay for services - Lack of awareness and information related to the collection time, the local strategy, and so on

In cases of mixed solid waste generation in tourism destinations (households, hotels and so on), the municipality is responsible for collection and transportation. In rare cases where the waste generator sorts their waste, two types of solid waste are eliminated: residual waste (collected by the municipality) and recyclable waste such as paper, cardboard, plastics, metals and glass (collected by private companies or informal collectors).

These actors are engaged in SWM activities without any special strategy. In practice, a bottom-up strategy is employed in Tunisia where waste is collected, landfilled and treated sanitarily, and small reducing, reusing and recycling actions are initiated.

5.1.2.3. CHALLENGES AND BARRIERS TO ADEQUATE SWM

Based on the data collected and analyses of the SWM in tourism areas in Tunisia, it could be concluded that both national and local authorities are spending a considerable amount of effort and finance to ensure the collection of waste from households, tourism establishments, streets and beaches. However, for many reasons, they cannot provide sustainable SWM. The causal analyses of the current situation has revealed the following main gaps:

Lack of Assessment in SWM Planning

To perform effective planning of SWM in tourism destinations, many parameters should be considered such as the stakeholders, the population and the number of tourists and tourism establishments. However, the population of tourism destinations in Tunisia is not stable as it varies according to the number of visitors and tourists. In fact, there is no concrete data upon which to conduct effective SWM planning. This data should, therefore, be collected and organised by local authorities, MLAE, and ANGED, in collaboration with the Ministry of Tourism, the Federation of Travel Agencies (FTAV), the Federation of Hotels (FTH), local NGOs and universities. Such data would be an excellent asset in supporting the decision-making process and SWM planning in these areas.

Unclear Responsibilities

SWM responsibilities between different stakeholders must be clarified. Municipalities are actually playing the primary role because they represent the local governances. Furthermore, since May 2018, the date of the last local elections where the aim was to decentralise decision making, they now hold considerable power. However, municipalities suffer from a lack of resources, infrastructure and the know-how needed to correctly perform their role. In large tourism destinations such as Sousse, Hammamet and Djerba, municipalities face additional problems ensuring a clean destination due to the massive quantities of solid waste generated. The central government is supporting this process seasonally and irregularly through APAL and the fund for the protection of tourism areas. However, the role of the FTH, the FTAV and indeed the hotels, in relation to SWM, remain neglected.

Unsustainable financing

Tunisia has also experienced several economic difficulties, especially after the revolution (Fanack, 2019). This has affected the service provided by the municipality as it has lacked the financial means to perform SWM correctly. Solid waste management in tourism destinations is financed mainly by the municipal budget and taxes paid by hotels (directly to the municipality and to the fund for the protection of tourism). However, the rate of recovering taxes from local citizens is insufficient and does not exceed 27%. Furthermore, the responsibility of waste producers, who put the packed goods into the market, remains very low, despite their membership of several waste recovery systems created by ANGED.

Unactivated waste sorting at source operation

Waste sorting at source in households and in tourism establishments (hotels, restaurants, and so on) is considered important in decreasing the amount of solid waste to be landfilled. Local governments in Tunisia do not strictly implement this process despite the existence of a framework law allowing a municipal order to apply this system.

The first priority of municipalities and national authorities is to ensure good collection of solid waste, in terms of whatever was mixed or sorted, to make the city clean and satisfy local citizens and tourists. Decision makers are cognisant of the importance of implementing waste sorting at source, which could decrease the amount of solid waste to be collected and treated and reduce SWM costs. Waste sorting could considerably change the composition of solid waste generated. Furthermore, some hotels are implementing small initiatives to sort recyclable materials for sale to private collection companies. In communities and households, local people do not pay attention to the benefits of selecting waste because, first, they do not have a clear infrastructure available to support this and, second, they are not aware of its importance, are not motivated to sort at source and do not receive any financial benefits from sorting.

Industries, tourist and local people's behaviour in SWM

Tourism destinations generate immense amounts of waste during the year, especially during the summer period, due to tourism activities and visitors to the city. In Tunisia, these zones have shown an increase in the total amount of solid waste generated over the last few years due to the growing number of tourists and the high occupancy rate in tourism establishments. Local people are not aware of the need to reduce and sort waste at source. It is common to see them leaving waste on the streets and beaches. Among the reasons for this are a lack of relevant education and communication programmes and the absence of an adequate infrastructure (bins on beaches or in the street, sorting bins, and so on). In addition, SWM programmes aiming to minimise, sort, and valorise waste in hotels are rarely established.

5.1.3. DISCUSSIONS

5.1.3.1. PROPOSED ORGANISATIONAL MODEL FOR SWM IN TOURISM ZONES IN TUNISIA

This research shows that the problems encountered by tourism municipalities in Tunisia are mainly caused by the lack of organisation between different actors, a lack of financial resources and the absence of planning, which itself is caused by the absence of data and considered as a key requirement for making good decisions. One key barrier is that of centralised decision making, where there is no involvement of citizens and local actors. After the election of May 2018, local authorities held a greater number of decision-making powers. To improve the level of SWM in tourism destinations in Tunisia, all actors and stakeholders should be involved so that each can contribute to the cleanliness of the area.

In this research, a proposed alternative model for the provision of SWM in tourism destinations in Tunisia was presented. The model shown in Figure 5-2 depicts the involvement of all stakeholders in most SWM procedures. Municipalities would be the main actor involved in managing solid waste; however, in terms of its implementation, the local government should cooperate with national authorities (tourism and environment ministries), the private sector (hotels, collection, sorting and recycling companies), NGOs and local citizens to formulate policies and create an appropriate SWM system.

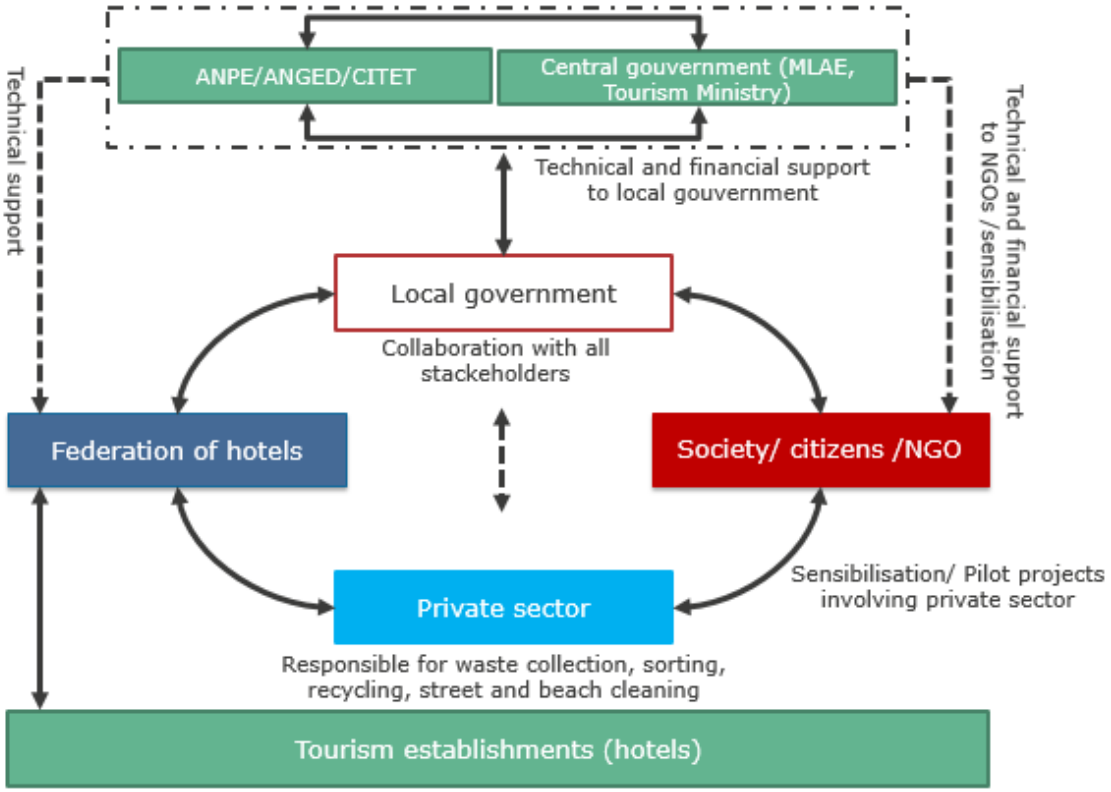

Figure 5-2. *Proposed scenario for SWM organisation in tourism in Tunisia*

The roles of stakeholders should be clearly defined as follows:

- **Central government (MLAE, Ministry of Tourism)** should play the role of a policy supervisor and financial supporter. Their tasks could include formulating national policies, standards and strategies, as well supporting municipalities by providing the knowledge and budget to facilitate their activities. Central government should coordinate its activities with related agencies such as ANGED, the International Centre for Environmental Technologies of Tunis (CITET), APAL, and so on.

Environmental agencies, ANGED, APAL, CITET: their role includes developing a suitable legal framework to improve the sustainability of the sector:

- **ANGED** is currently playing an important role in waste treatment and in supporting recycling and valorisation initiatives. It should also support this sector through the implementation of an EPR system, which will ensure sustainable financing of SWM in Tunisia. Moreover, ANGED should also continue raising awareness among NGOs and citizens in tourism areas.
- **CITET** is to support tourism establishments through education and technical support programmes to improve their internal SWM systems. Additionally, CITET should also have sophisticated laboratories available that enable it to push for scientific research, especially with regard to transferring its experience to the composting of organic waste.
- **APAL** should continue contributing in supporting tourism municipalities to keep beaches clean during the year. They should also take charge of sharing awareness and communication with visitors on beaches.
- **Municipalities** should take part as a policy maker at a local level, taking into consideration the national strategy and standards. The formulation of policies should be developed in concert with the private sector, society and citizens, and local NGOs. In addition, municipalities should retain the role of public service provider through the collection and transport of collected mixed waste. To encourage the waste producer (principally hotels) to minimise generated waste and reduce mixed waste, incentives should be applied to the collection of recyclable materials.
- **SWM private companies** represent the public service partners playing their roles as solid waste service providers and policy formulation partners.
- **Society, citizens and local NGOs** represent key partners. They should be engaged in policy formulation and implementation, control the management process and cooperate in the provision of services. Local citizens are requested to participate in local efforts to sort the generated waste at source and coordinate with local NGOs and local governments.
- **Hotels and other accommodation establishments:** In addition to their role in financing the municipality's services and the Fund for Tourism Protection through paying hotels taxes, these businesses should participate in local efforts to reduce the

waste, and to sorting it at source. The coordination of all this operations should be coordinated with the FTH (Figure 5-3).

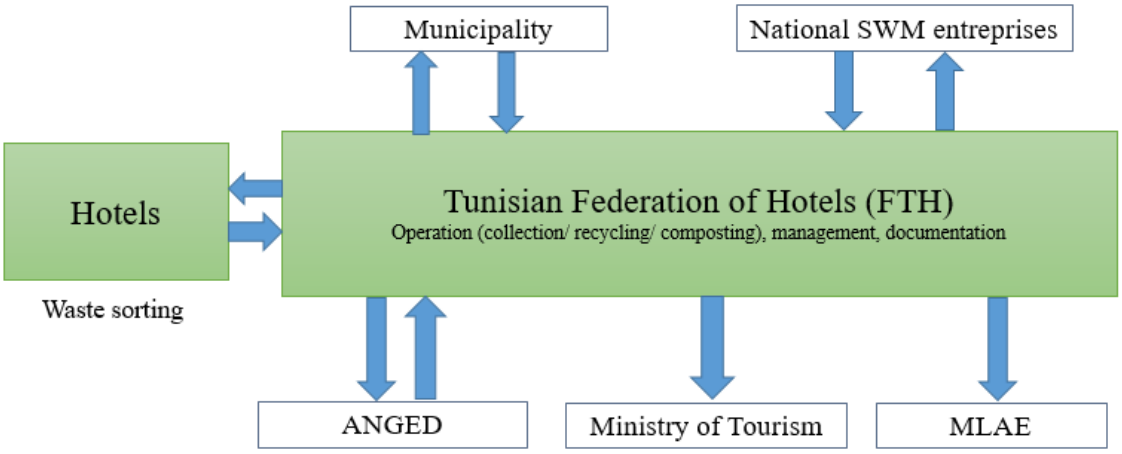

Figure 5-3. *Proposed scenario for hotel's waste management operation*

It is also recommended that hotels develop their sustainability and environmental certificates (such as Eco-label, Travelife, etc.), which could support their process toward reducing waste, sorting at source, ensuring a good disposal, educating the staff, etc. In addition, hotels must work on the mapping of the waste generated within the business, which could help to identify areas where simple measures can be implemented to minimise waste and save money. In addition, tour operators could take part in communicating with the tourists about the hotel's environmental initiative.

- **Tunisian Federation of Hotels:** The FTH is considered a key actor in this process. It represents the link between local hotels and the municipality and its participation in the development of local strategies related to solid waste generated from hotels represent an asset. The scenario developed in Figure 5-3 indicate the crucial role that could play FTH in the operation, the management and the documentation of the sorted solid waste generated from hotels, in coordination with the main actors, such as the local authority, MLAE, ANGED and Ministry of Tourism. It is also possible that the FTH delegates the collection and secondary sorting tasks, or the composting of clean organic waste, to competent local or national companies. Alternatively, the federation could also manage the system through creating its own company. Either way, this should be accompanied by the strong commitment of all actors to reach to collection and valorisation goals set at the local level. FTH should, therefore, be involved in the decision-making committee managed by the local government, especially when planning relevant actions, especially when setting the SWM objectives. Figure 5-4 presents an overview of the recommended organisation of the SWM in tourism areas in Tunisia.

Role of actors			
	Central government	- National policy and standard - Financial support to local government	Policy supervisor & financial supporter
	ANPE/ ANGED/ CITET	- Technical support to hotels, FTH - Control and follow up of the process.	Policy supervisor & technical supporter
	Local government	- Formulate policies in concertation with other partners - SWM service in the tourism destination	Policy maker Service provider
	Private sector	- Policy partner - Service provider and operating following the standard	Service provider & partner
	Society/ Citizen / NGOs	- Partner in the SWM process (respecting laws, sorting at source) - Developing pilot projects	Partner & beneficiary
	Federation of hotels	- SWM strategy development – main partner - Coordination and control of the SWM process - Decision-making main partner	Key partner
	Hotels	- Waste sorting at source - Support the municipality (beaches and streets cleaning) - Coordination with FTH	Partner & contributer

Figure 5-4. *Role of different partners for SWM in tourism areas*

In addition to the commitment of all stakeholders, achieving the goals of this partnership should be supported by the following actions:

- **Raising awareness** and changing the attitudes of both the public and industries towards SWM through the implementation of environmental education programmes. The latter should focus on waste minimisation, waste sorting at source in households and hotels, and the storage of waste in good conditions. Planning for education and awareness campaigns should consider national and local objectives, the target population, and the overall framework and socio-economic factors to ensure greater effectiveness.
- **The prevention and minimisation of solid waste,** based on the Three Rs (3R) approach, is the best way to manage waste, reduce landfilled waste, and thus reduce SWM costs including the costs of waste recycling, transportation and disposal/treatment. For this reason, waste reduction and prevention should be the highest priority when formulating SWM strategies in tourism destinations.
- **Waste recycling and composting:** To motivate tourist establishments and local citizens to ensure the correct sorting of recyclable materials, local collection and recycling companies in tourism destinations need to ensure the correct collection and valorisation of the generated waste. Cooperation between waste generators, collection and recycling companies, and other actors should be convenient, inexpensive and with fewer barriers for all partners. In addition, the local government and private sector should implement pilot projects for composting green and clean kitchen waste. Education and exchange programmes should also be implemented.

- **Role of the private sector:** Solid waste management programmes should be developed between the private and the public sector (in the framework of a public–private partnership [PPP]). The formulation of contracts is an important factor that will help ensure the success of this partnership. Collaboration with the public sector should involve not only large or international companies, but also the local private sector, micro-enterprises and local engineering offices.
- **The integration of the new concept with the national vision and sustainable projects:** The organisation of the new concept should take into consideration the national vision and orientations. For example, in Tunisia, the valorisation of materials through the mechanical and biological treatment is currently the vision of the government. This will be combined with the implementation of the international concept EPR, which must be adapted to the Tunisian concept.

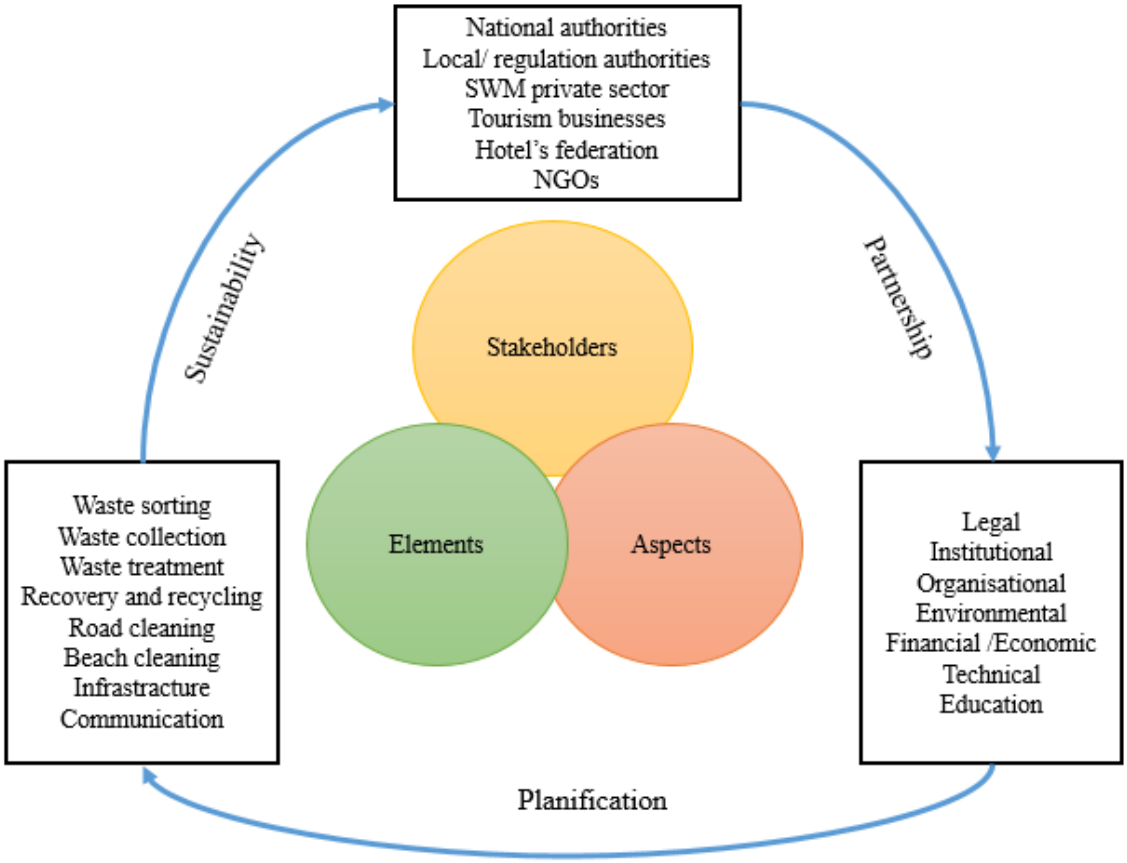

Figure 5-5. *Possible stakeholders, elements and aspects of an integrated and sustainable SWM in tourism*

Proper SWM is an important element in supporting the role of the tourism sector in the national economy. Discussions with tourists and visitors has shown that they seek an intact environment that is free of garbage in the roads and beaches or floating in the sea, which confirms the idea reported by Prabhakar et al. (2016).

In practice, the SWM role played by the national and local government involves the collection, transportation and landfilling of waste, while citizens and the tourism industry

establishments are in charge of paying a service levy. Due to the rapidly increasing volumes of solid waste that are generated and accumulated in tourism destinations, municipalities in Tunisia spend a lot of money and effort ensuring a clean destination, mainly for waste collection. It is likely that more money will need to be spent on tackling this issue if SWM in tourism areas is not carried out in an effective and proper manner, and if no efficient and sustainable SWM practices are put into effect.

Performing collective efforts from all concerned parties is required to ensure a fruitful SWM system in tourism destinations in Tunisia. Such a system should consider both economic and social aspects. To achieve this target, an integrated approach should be considered. Integrated thinking for the recovery of materials is the key to a SWM system that can transform the waste in the tourism sector from being the source of environmental problems to becoming a solution. In the new model, both national and different local stockholders in Tunisia should be involved in improving the cleanliness of their cities and sharing the pressure. The position of local society and industries in this model is considered as both a public service customer and an active public service partner.

Furthermore, to make substantial progress towards sustainable SWM in tourism destinations in Tunisia, it is necessary to propose and develop concrete targets. The proposed targets should have a clear vision and objectives, and be designed with clear indicators. However, these can be adapted anytime to the change in the framework. The implementation of the model requires the consideration of environmental, social and economic aspects. In so doing, it will create an SWM system that is environmentally sound, economically viable and socially beneficial.

Based on the diagnostic of the organisational statue, this section presents possible organisational scenarios that could improve the SWM in tourism destinations in Tunisia. This scenario is mainly based on cooperation between different stakeholders, while detailing and clarifying the responsibility of each actor. In the next chapter (5.2), the solution combines both financial and organizational aspects, through developing an adapted EPR concept for Tunisia. The latter should consider the specificities of tourism areas in the country.

5.2. Establishing Extended Producer Responsibility For Packaging

Packaging aims always, but not only, at protecting a specific product. Accordingly, the materials used in packaging and material compositions are polyvalent. The multitude of products is increasing everywhere and exchanging goods is no longer limited to the domestic market in every country around the world (Pascal et al., 2018). Similar situations arise in supermarkets across the world, where packaged goods from large international businesses dominate and the wide variety of colours, shapes and materials encourage consumers to make purchases. Packaging waste is actually a relevant resource, although it has not always been shown to have a positive market value. Indeed, recycling, or at least energetic recovery, has several benefits over other waste management options. It reduces production costs, the demand for landfill related facilities, saves energy and natural resources, and generates job opportunities (Nahman, 2010). Unfortunately, in many countries, including those of the MENA, levels of packaging recovery remain very low; for instance, 10% in Egypt, 8% in Algeria, 5% in Bahrein, 5% in Iraq, 3% in Libya, 5% in Tunisia, and so on (Nassour et al., 2018).

Indeed, EPR is an increasingly popular instrument for solving SWM problems (Fleckinger & Glachant, 2010). It is an environmental approach based on the polluter-pays principle, whereby those who introduce packaging or packaged goods into a country's market remain responsible for them until the completion of the packaging life-cycle. The extent of producer responsibility depends on the specific model applied and is usually only financial, although in some cases it is also organisational (European Commission, 2014). In this system, companies that introduce packed products into the market are obligated to collect, sort and recycle the packaging of these goods or dispose of them in an environmentally friendly way as soon as they have reached the end-of-life-phase (OECD, 2016). In the meantime, there are a multitude of approaches and systems in many countries, which are referred as 'EPR systems' (OECD 2013).

EPR could represent a key solution for the management of packaging materials in Tunisia, based on developing organisational solution, to improve the financial aspect of the waste management sector not only in tourism, but in all the country. The EPR should be based on a participatory approach detailed in the previous chapter (5.1), including the important role of the producer to contribute in a sustainable and concreate system.

Several key questions arise in relation to solid waste generated in tourism areas, which is increasingly impacting upon the environment: Who will assume the responsibility for all the packaging that is no longer needed after only a very short service life? Who should ensure that packaging is recycled after use or disposal? Who is responsible for the organisation of the SWM system in tourism areas? Who should bear the costs?

5.2.1. Methods and Field Work Description

5.2.1.1. DIAGNOSTIC OF THE CURRENT ECO-LEF SYSTEM

The starting point for introducing EPR in Tunisia is enabling an inclusive discussion between all stakeholders related to the SWM sector and the existing ECO-Lef system.

Table 5-2. *Key actors involved in the diagnostic phase.*

Institutions	Mission
MLAE	The MLAE is responsible for elaborating strategic concepts and supporting SWM activities.
ANGED	ANGED is currently the first body that is responsible for the organisation and the operation of the ECO-Lef system.
Tunisian Union of Industry, Commerce and Handicrafts (UTICA)	This structure brings together the professional structures of the different economic sectors. Its mission is to promote the private sector and to be the spokesperson for companies with the public authorities. The foundation includes private collection and recycling companies, as well as producers and manufacturers.
Ministry of Finance	The Ministry of Finance is responsible for collecting eco-taxes and financing a part of the ECO-Lef budget and SWM operations.
Ministry of Tourism	The Ministry of Tourism ensures the implementation of the government's policy in the field of tourism. The main concern of this sector is sector is to have clean beaches and destinations and to attract more tourists to the country.
Federation of Hotels (FTH)	The federation aims to contribute to the promotion of the hotel industry within the framework of the national economy.
Private sector (collectors and recyclers)	Private collectors and recyclers represent key actors in this process. Their presence in tourist destinations can open the doors to more recycling and more sorting at source initiatives.
Producers, manufacturers (national and international companies)	The entity whose brand name appears on the product itself or the importer. In the case of packaging, the filler of the packaging is considered the producer. They are members of UTICA.
National Institute of Statistics (INS)	The INS is a public establishment responsible for the production and analysis of official statistics in Tunisia.
Packtec	The Technical Centre for Packaging (PACKTEC) aims to improve the competitiveness of the sector through assistance, consultation and technical services related to packaging, transport, logistics and impression.

Producers, waste management companies, decision makers and civil society should discuss the best EPR scheme for the country, taking into account the local conditions such as waste composition and volume, the attitude of the public when disposing of waste, what capacities waste management companies have and need, and resources of the local

authorities to implement the SWM plan and EPR scheme. The communication and cooperation between all actors is imperative to a successful EPR scheme.

To diagnose the current solid waste recovery and recycling system in Tunisia, several visits were made to different institutions and national and local authorities relevant to the sector. After collecting basic information about the situation, basic principles of EPR and international experiences related to the concept were presented and discussed to introduce the concept of EPR, its objectives and organisation for it to be considered as a new approach for the Tunisian authorities. The concerned actors and their respective current roles are presented in Table 5-2.

The purpose of these visits was to understand existing organisational and legal frameworks, and collect data related to the ECO-Lef system. In addition, the financial framework (the financing of the system and its costs) was also analysed. A participatory approach was employed to discuss possible optimisation scenarios during these meetings.

5.2.1.2. EXTENDED PRODUCER RESPONSIBILITY PRINCIPAL

According to the OECD (2016), EPR is "an environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product's life cycle". In practice, EPR recommends that producers assume responsibility for collecting or taking back used goods and for sorting and treating them prior to eventual recycling. The concept is presented in Figure 5-6 below:

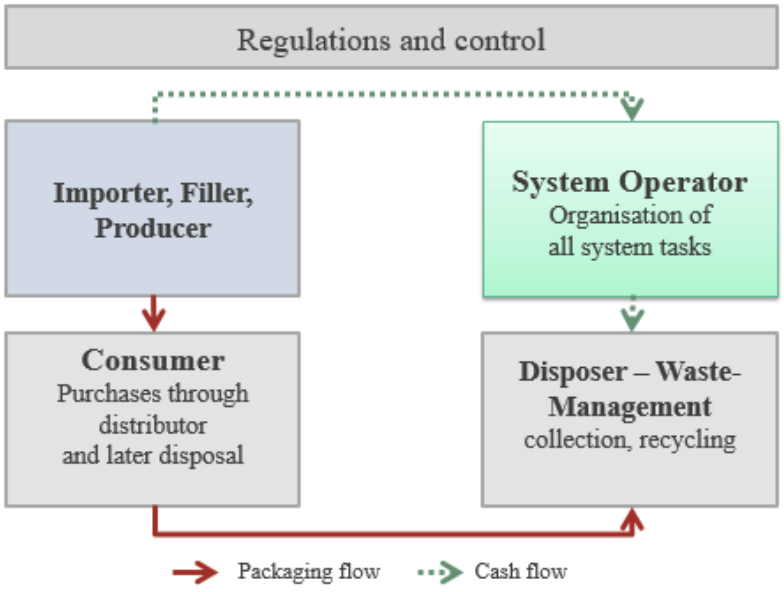

Figure 5-6. *Typical EPR model*

To transform individual responsibility into collective responsibility, a concrete EPR organisation (system operator, producer responsibility organisation) should be established. Those producers and importers responsible for the financing and the organisation of the EPR system must, therefore, organise or assume the system

responsibility through a predetermined form of organisation. This institution is then referred to a system operator.

The producers of products subject to EPR should be clearly defined. According to the OECD, the 'producer' is defined as the entity with the greatest control over the selection of materials and the design of the product.

5.2.1.3. WASTE SORTING ANALYSES

The characterisation of the solid waste generated was held in different municipalities. Three different municipalities were studied in Tunis: one high income municipality (Sidi Bousaid), one middle income (Bardo), and one low income municipality (Hrairiya). Unemployment in these municipalities is at 8.97%, 12.73% and 17.02%, respectively. In addition, waste generated from households and hotels in the Hammamet municipality were analysed.

The objective was to identify the potential of recovery of the recyclable materials from the waste generated. The waste fractions were divided into 18 primary categories and 34 sub-categories. A screen unit with a 100 mm, 50 mm and 20 mm screen was used to screen the waste to fractions > 100 mm , between 50 mm and 100 mm, fractions between 30 and 50 mm, and fraction >30 mm.

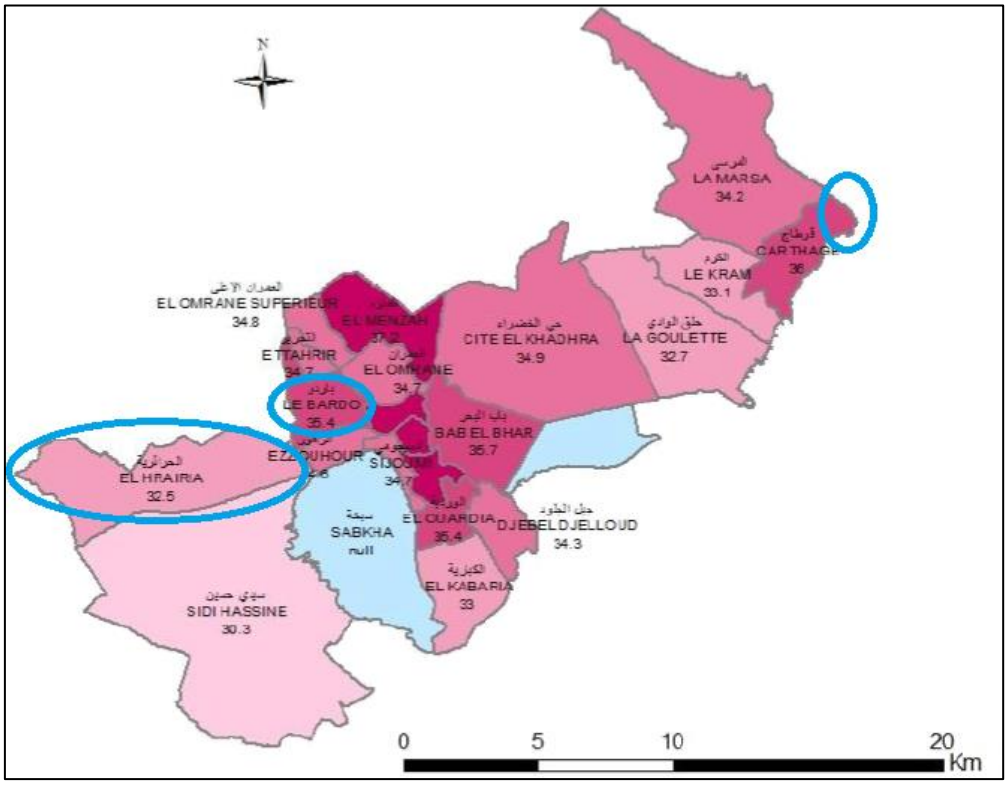

Figure 5-7. *Cartography of the sorting analyses study areas in Tunis governorate*

The characterisation was performed in private centre in Tunis and Hammamet with the support of five workers. The analysed samples represent 1% of the total waste generated during one week in each zone.

As a first step, plastic bags containing the waste were opened to make the contents available for screening and sorting. After screening the entire waste samples (see the used screener in Figure 5-8), the separation of the waste into four categories, where waste bigger than 100 mm and fractions between 50 mm and 100 mm was then placed on a table and sorted manually.

(a) *(b)*

Figure 5-8. Sorting analyses sieve unit (a and b)

5.2.2. Results of the Diagnostic and agreed scenario

5.2.2.1. DIAGNOSTIC OF THE CURRENT WASTE RECOVERY AND RECYCLING SYSTEM (ECO-LEF)

Post-consumer packaging waste represents a significant problem in Tunisia. Eliminated items such as cans, yoghurt cups, flexible plastics, plastic bottles (PET), etc. can be commonly seen littering the roads, public spaces, beaches and marine environment.

Since the promulgation of the framework law N° 96-41 on SWM and the related application texts, Tunisia has set up several collection systems, treatment and valorisation of packaging waste.

The packaging targeted by the ECO-Lef system are plastic and metal packaging (with a capacity greater than or equal to 100 ml), mainly bottles of soft drinks and water (PET), milk bottles (HDPE), plastic films and bags (made of PP) and metal boxes (aluminium). However, cardboard packaging is not subject to any organised system. This system led to the development of 318 ECO-Lef points and the collection of plastic packaging waste that reached its peak in 2008 with the collection of 15,700 tonnes of packaging waste. Depending on the type of polymer, 70% to 90% of the collected plastic waste was recycled.

Recycling companies are also involved in this sector on several levels since they have their monthly quotas collected by the ECO-Lef points; they also accept products collected by the individual collectors. Some NGOs are also involved in the activity through the awareness campaigns and the initiation of pilot projects aimed at the collection and the recycling of PET bottles, PEHD products and cans.

ORGANISATIONAL STRUCTURE

The results of the analyses of the organisational stracture (Figure 5-9) shows that ECO-Lef comprises the collection of recyclable materials under the terms of conditions and agreements of ANGED, and also the recycling of plastic waste under the terms of reference and agreements for obtaining monthly quotas of these materials from ANGED. The system was created to reduce the landfilling of packaging waste, limit the negative impact resulting from the exorbitant amount of packaging waste in nature, and promote the recycling and recovery of packaging waste.

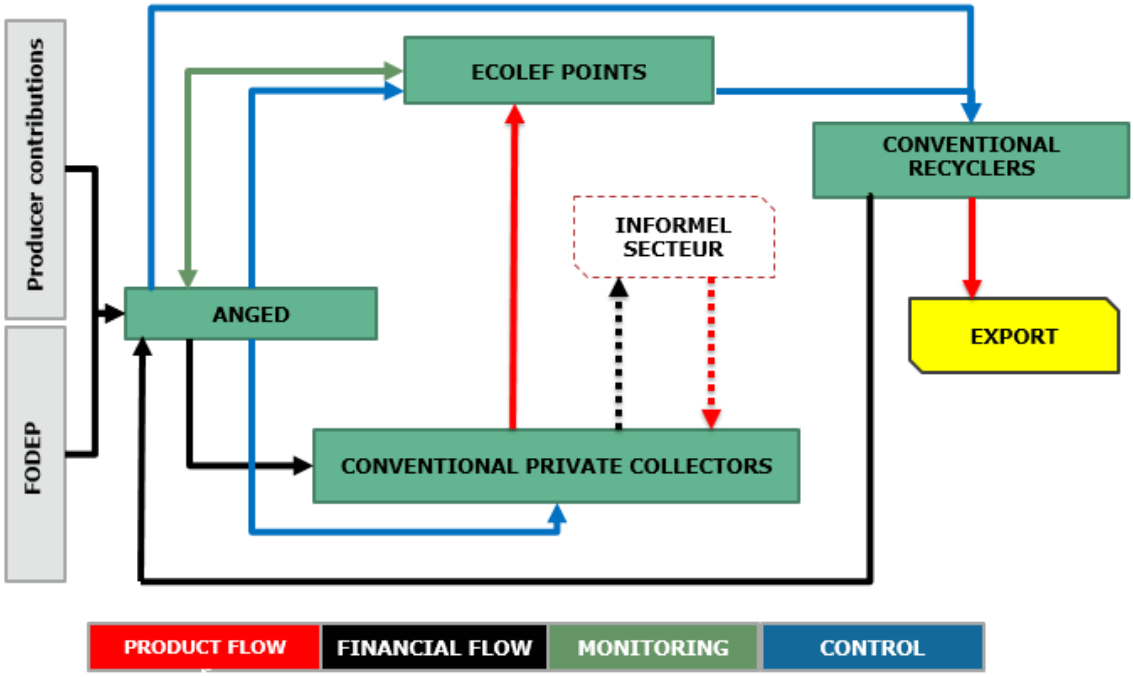

Figure 5-9. *Financial, products, monitoring and control flows within the ECO-Lef system*

MATERIALS COLLECTION

The collection of recyclable materials within the ECO-Lef system is realised by small companies that are approved and authorised by ANGED. The authorised collection companies buy the materials from the informal collectors "Barbechas" and pay them directly after weighing. The collection companies sell the collected amounts to ECO-Lef points, however, they are not obliged to sell the material to the system. These points are responsible for recording the collected quantities, compacting them and preparing it to be sold to recycling companies.

ECO-Lef points are installed across the country. In most cases, these points are installed on municipal property. The staff are hired by ANGED and the number of workers for the system is actually 380 (paid for by the system). The results of the data collection from different ECO-Lef collection points from ANGED highlighted the change of the number of ECO-Lef points from 2003 to 2017 (Figure 5-10):

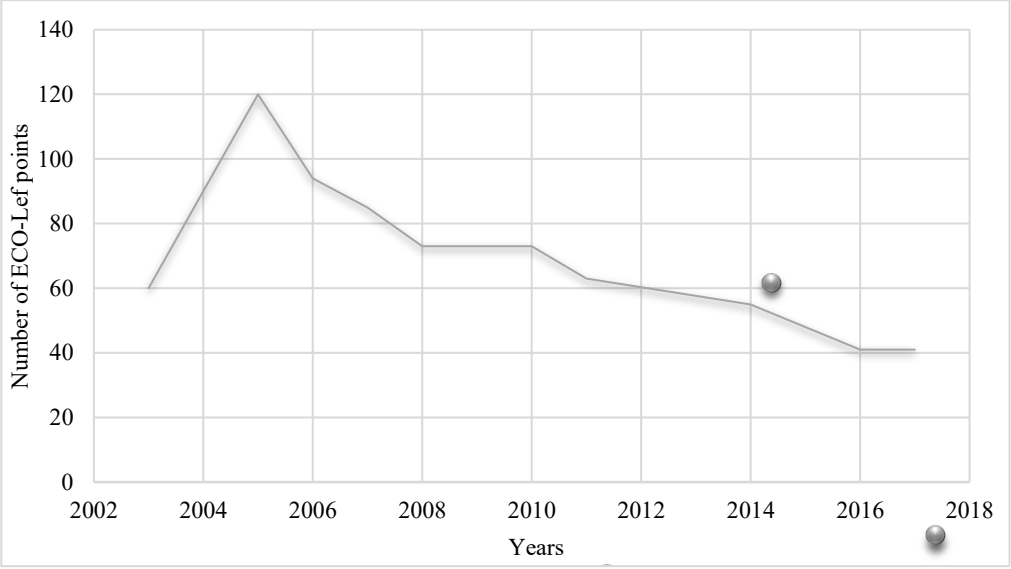

Figure 5-10. *Evolution of the number of ECO-Lef points from 2003 to 2017*

The main reason is indeed the development of the parallel collection of packaging by private collectors (private collection points). Several micro-enterprises have been developed and are delivering directly to recyclers formally. In addition, the lack of equipment and resources necessitated the closure of other points. The evolution of the collected quantities by ECO-Lef points is presented in Figure 5-11:

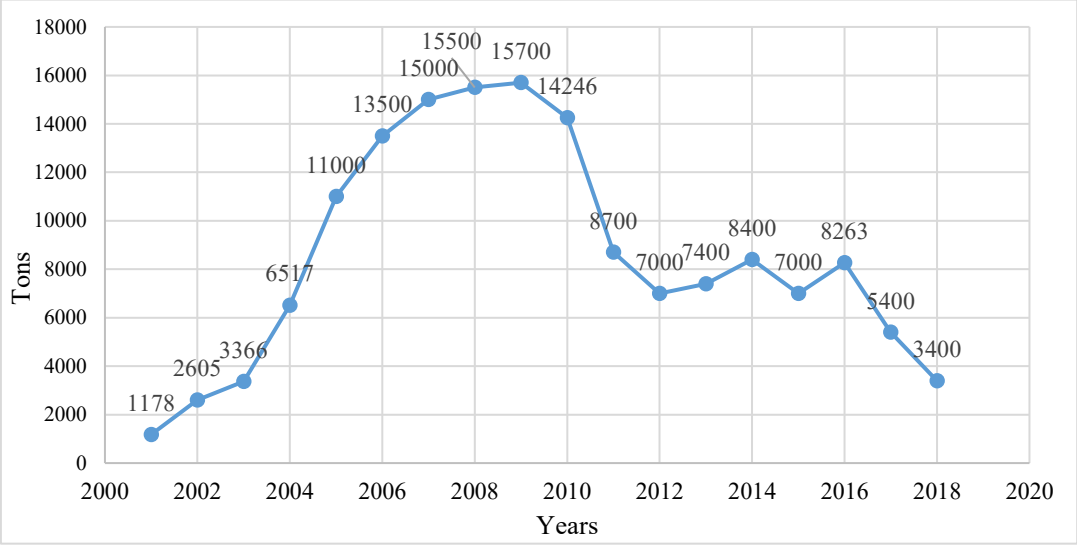

Figure 5-11. *Evolution of the quantities of plastic collected through ECO-Lef (ton/year)*

The collected quantities via the ECO-Lef system have decreased considerably since 2009, reaching 5,400 tons in 2017 and 3,400 in 2018. The small increase in quantities collected in 2014 can be explained by the increase in the purchase price of PET by the ANGED from 0.5 TND to 0.75 TND per kilogram. Table 5-3 presents the current sale price for ANGED and for the recycling companies within the ECO-Lef system. In April 2019, ANGED decided to increase the purchase price for the collectors to reach 1.150 TND and

up to 0.65 TND as selling prices for recyclers. These procedures did not lead to the improvement of the collection results.

Table 5-3. *Market of the different recyclable materials through the ECO-Lef system.*

Nature of packaging	Price paid by ANGED to collection companies (TND/Kg)	Price paid by recycling companies to ANGED (TND /Kg)
Polyethylene terephthalate (PET) plastic bottles, (mineral and aerated waters)	0.75	0.25
High Density Polyethylene (HDPE) plastic milk bottles	0.500	0.1
Plastic films	0.500	0.3
Cans of cosmetics and cleaning products	0.500	0.1
Bottle stoppers	0.500	0.1
Plastic packaging bags	0.500	0.30
Metal tins (tin)	0.180	-
Plastic stretch films	0.500	-

Furthermore, Table 5-4 presents the most collected materials within the ECO-Lef system in 2016. It indicates that the collection of PET plastic bottles represents 67% of the total quantities, followed by plastic membranes with nearly 29%.

Table 5-4. *Quantities of different collected materials by ECO-Lef system in 2016 (ton/year).*

PET bottles	Flasks of milk	Plastic membranes	Bags with cradles	Metal cans	Caps for bottles	PEHD (cleaning products)	Films	Total
5575	96	2368	14	0.3	32	126	55	8267

MATERIALS RECYCLING

After the compacting of the collected quantities, ANGED allocates it equally to all recycling company members of ECO-Lef. The quantity is prepared to be exported or to be recycled locally.

Regarding plastics recycling activities in Tunisia, it is important to distinguish between PET and HDPE. Usually, PET is collected, cleaned and milled (a pre-treatment before the final recycling), and is then exported to different countries such as Turkey (and in the past to China). In fact, ANGED does not have data about the exported material, since it is managed by traders. Reasons for exporting are based on the better prices due to the exchange rates and the lack of infrastructure in Tunisia. In addition, HDPE is collected, cleaned, crushed and processed into raw material in Tunisia. Figure 5-12 below shows the evolution of the number of recycling companies in the country from 2003 to 2017.

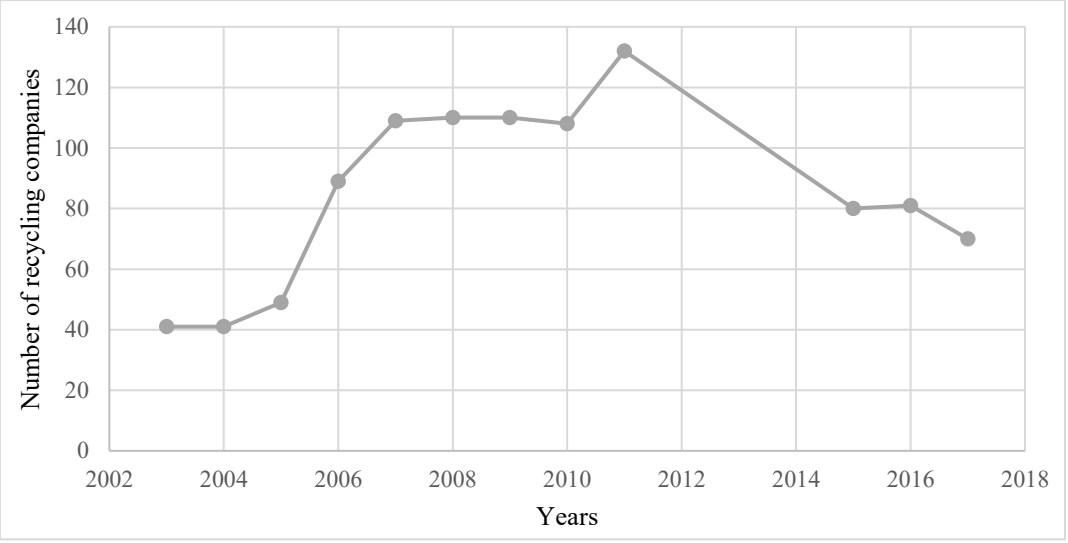

Figure 5-12. *Evolution of the number of recycling companies approved by ANGED*

The number of recycling members of ECO-Lef has decreased since 2011. Only 70 companies are actually active in the system. The rest stopped their activities for various reasons (technical, administrative, financial and logistic problems).

However, the information that is still missing for the government is the quantities actually recycled by recycling companies, which covers both streams of waste collected through ECO-Lef and the waste directly collected.

In order to better understand the potential of the collection and recycling of materials in Tunisia, a sorting analyses was carried out in three different zones with different income levels. The results of the sorting analyses (Table 5-6) showed that several materials of the total waste generated in Sidi Bousaid, Hrairia and Bardo represents an opportunity for recycling. Unfortunately, waste is collected by the municipality without any separate collection, and landfilled in Borj Chakir Landfill located at 32 km from Sidi Bousaid, 5 km from Hrairia and 11 km from Bardo.

The objective of this sorting analyses is to identify the potential of recyclable materials collection and recycling in Tunisia. The results shows that the generated waste fractions depends on the incomes of the population. Sidi Bousaid municipality, where the income level is important generates more recyclable materials and packaging (Paper and cardboard, plastic, glass, aluminium) and at a lesser proportion Bardo and Hrairia.

Table 5-5. *Results of the sorting analyses for households waste in Bardo, Hrairia and Sidi Bousaid municipalities (Tunis governorate).*

Material Fraction – Supergroup	Material fraction	Examples	Bardo %	Bardo	Hrairia %	Hrairia	Sidi Bousaid %	Sidi Bousaid
1. Organic waste	1.1. Vegetable food	Fruits, Vegetables	35.5	43.9	58.3	67.5	16.1	24
	1.2. Animal based food	Meat products	2.1		2.05		0.8	
	1.3. Other organic waste	Lawn cuttings, Tree cuts	6.3		7.11		7.1	
2. Paper and cardboard and Paper compound	2.1. Paper package and small cardboard boxes	Cardboard boxes of food, shoes, electrical appliances	0.5	18.9	0.12	10.3	0.7	25.1
	2.2.Cardboard boxes - Transport packaging	Large cardboard boxes, which are usually not used in the household, but in trade, commerce or industry	1.6		0.94		1.1	
	2.3. Paper compounds for food with direct contact with the contents, but not liquids	Plastic coated cartons such as for example freeze packaging for spinach, pizza boxes and composite cans	3		0.80		5.3	
	2.4. Carton packages for liquid food	Tetra Pak, (e.g. for milk, juice, tomato purée, cream)	1.2		0.63		2.2	
	2.5. Other paper waste without packaging	Paper tissues, magazines, booklets, sheets	12.6		7.83		15.8	
3. Glass	3.1. Glass packaging	Beverage bottles, cans,	3	3.9	1	1.4	7.8	10.6
	3.2. Other glass items (without packaging)	Breakage of window glasses, vases	0.9		0.4		2.8	
4. Plastic	4.1.Films< DIN A 4	Films from households for food	1.7	12.1	1.3	6.2	3.5	17.6
	4.2. Films> DIN A 4	Films from garden markets, agriculture	0.9		0.5		1	
	4.3.Plastic bags and carrier bags	Plastic bags for fruits, vegetables, meat and plastic carrier bags of all kinds	4.1		2.2		4.2	
	4.4. PET beverage bottles	Bottles for water and soft drinks	3.7		1.6		6	
	4.5.Other bottles (without PET beverage bottles)	Bottles for shower gel, shampoo, cleaning agent,	0.5		0.1		1	

Material Fraction – Supergroup	Material fraction	Examples	Bardo %	Bardo	Hrairia %	Hrairia	Sidi Bousaid %	Sidi Bousaid
	4.6.Other plastic packaging (without films, bags and bottles)	Yogurt cups, margarine cups, sausage packages, bowls for fruit or vegetables	0.6		0.2		1.1	
	4.7.Other plastic	Children's toys, bottle stoppers, shoes	0.6		0.29		0.8	
5. WEEE	5.1.WEEE	Electrical and electronic waste	0.3	0.3	0	0	0.1	0.1
6. Tinplate and tinplate compounds	6.1.Tinplate beverage cans (top cover aluminium)	Cans	0.8	1.9	0.49	1.35	0.2	2.9
	6.2.Tin cans	Cans for vegetables, processed tomatoes	0.9		0.81		2.6	
	6.3.Other tinplate packaging	Cans for hair spray, deodorant spray, bottle stoppers	0.2		0.05		0.1	
7. Aluminium and aluminium compounds	7.1.Beverage cans made of aluminium	Cans	0.5	1.1	0.2	0.5	1.5	3.4
	7.2.Other cans made of aluminium	Spray cans, food cans	0		0		0.3	
	7.3.Other packaging mainly consisting of aluminium or having aluminium proportions (aluminous compounds)	Coffee bags, coated bowls for pet foods, toothpaste tubes made of plastic covered inside with aluminium, tablet blister, closures of bottles	0.27		0.1		0.5	
	7.4.Other aluminium objects, items' packaging	Household goods	0.32		0.2		1.1	
8.Other metals	Other metals without packaging	All kinds of scrap	0.3	0.3	0.1	0.1	0.1	0.1
9.Textiles	Textiles	Clothing and household textiles	3	3	1.4	1.4	2.4	2.4
10.Batteries	Batteries	Batteries from all areas of application	0.1	0.1	0.1	0.1	0.1	0.1
11.Hazardous material	Hazardous material	All hazardous material without batteries	0.1	0.1	0.1	0.1	0.1	0.1
12.Other mineral waste	Other mineral waste	Stones, rubble	1.8	1.8	3.1	3.1	0	0
13. Fine waste	Fine waste	Waste <30 mm	7.3	7.3	5.6	5.6	10.7	10.7
14.Undefined waste	Undefined waste	All wastes not listed under items 1 to 15	5	5	2.4	2.4	0	0
15.Wood	Wood	Wood	0.3	0.3	0.1	0.1	3.5	3.5

Table 5-6. *Quantities of sorted samples and percentage of different fractions.*

Quantity (kg)									
Zone	**>100 mm**	**%**	**0-100 mm**	**%**	**30-50 mm**	**%**	**>30 mm**	**%**	**Total**
Bardo	1,328.2	54.3	444.8	17.8	397.2	16.2	274.8	11.2	2,445
Hrairia	1,309.3	46.1	680.7	23.9	590.7	20.8	259.7	9.1	2,840
Sidi Bousaid	541.1	52.6	159.5	15.8	187.5	18.5	121.0	12.0	1,009

Currently, many recyclable materials are not considered by the ECO-Lef system, and only some available recyclable materials which are easy to pick up, and having a marked value are collected by the waste pickers and waste collection companies. The reason is also the absence of adequate infrastructure and technologies to recycle some materials.

The outcomes of the sorting analyses shows also the importance of the development of a system, where a correct separation at source is applied, which leads to higher recycling rates with a better quality of materials and less contaminations. According to Cyclos GmbH, several waste recyclable fractions could be collected separately such as:

PAPER/CARDBOARD/CARTONS

Packaging made from paper/cardboard/cartons are based on renewable raw materials, either as primary fibres from renewable wood (so-called reclaimed wood or thinning) or as secondary fibre from recycled waste paper. Waste paper recycling is nearly a closed material cycle. Paper for packaging purposes can be produced again from packaging made from waste paper. In doing so, special requirements can be met for food contact paper. One paper fibre can be recycled seven to eight times.

TINPLATE

Tinplate or steel for packaging can be used, for the most part, in the packaging sector, e.g., for packaging food, beverages, aerosols, paints and lacquers. Sorting is necessary with separated collection of light-weight packaging. By equipping the sorting equipment with magnetic separators, tinplate, as a fraction, is sorted with high accuracy. These are used again in steel production for manufacturing new steel.

ALUMINIUM

Aluminium packaging or packaging containing aluminium are processed into aluminium parts that can be used further with either dry-mechanical processes or in pyrolysis plants (pyrolysis to clean the aluminium before the melting step). Aluminium can be recycled as often as desired and without loss in quality.

PLASTICS

The individual types of plastic have special attributes and properties, which substantially influences the use and disposal of these plastics. The most predominant plastic types, by

far, used for packaging are PET (polyethylene terephthalate), PE (polyethylene), PP (polypropylene) and PS (polystyrene).

PET (polyethylene terephthalate)

Polyethylene terephthalate **(**PET) is used as a packaging material in the form of film packaging, blister packs and bottles. By means of various material recycling, the used plastic packaging can either be processed into flakes or into regranulate. Processing for bottle-to-bottle recycling meets the high hygiene requirements for plastics in contact with food. Used PET bottle are also used in the manufacture of textiles.

PE *(polyethylene)*

Polyethylene (PE) is the most produced and used polymer. Polyethylene with high density (HDPE) and polyethylene with low density (LDPE) are differentiated. The former, HDPE, is harder and stiffer than LDPE, tolerates higher temperatures, and is less permeable to gasses and more resistant to chemicals. The latter, LDPE, is more resilient, more elastic, and more flexible than HDPE.

Packaging made of PE can be easily recycled. By means of various material processes, the used plastic packaging can either be directly re-melted into new products or processed into regranulate. This grainy recycling polymer is a cost-effective alternative compared to new goods and is a high-quality raw material for the plastic processing industry. The product range for recycled PE is versatile: Films, garbage bags, buckets and barrels, garbage cans, drinking water pipes, landfill liner systems, cable insulation, etc.

PP (polypropylene)

Polypropylene (PP), in its properties and construction, is similar to PE and a thermoplastic polymer closely related to HDPE. By means of various material processes, the used plastic packaging can either be directly re-melted into new products or processed into regranulate.

PS (polystyrene)

Polystyrene (PS) is a polymer that is used either as a thermoplastic polymer or as a foam material (EPS). Further, PS can be processed by mechanical commutation to regranulate. It can be materially recovered by melting/re-melting in the injection moulding process. Polystyrene products are well suited to this since the properties of the material are also changed only non-substantially after multiple processing.

Flexible plastics and mixed plastic materials

These include, for example, plastic films, bags or other packaging, e.g., shrink-wrapped goods, which can consist of one or more types of plastic. The plastic packaging can be recovered as a material, raw material or energy. It is initially important that this plastic packaging is collected and, consequently, that the surrounding area is kept clean. Material recovery is possible with flexible plastic packaging if the separation of plastic types, e.g.,

a pure polyolefin fraction, can be generated. Buckets, plastic cages and boxes, for example, can be produced from regranulate.

Mixed plastic materials can be melted down into somewhat thicker-walled products. Moreover, processing and use is practical in cement factories. Valuable raw materials can be conserved through these measures. However, in all cases, it must be assumed that additional payments are necessary for the recovery of flexible plastics and mixed plastic materials since the financial expense of cleaning and processing mixed plastic materials cannot be covered using potential earnings.

INFORMAL SECTOR

Waste collection and recycling is a pressing topic in Tunisia because many people are involved in this activity and most of them do not work in a formal way caused by their socio-economic conditions. This phenomenon can be observed in all cities across the country and in poor and rich districts. The results of the diagnostic of the activities of formal and informal sectors has been summarized in Figure 5-13.

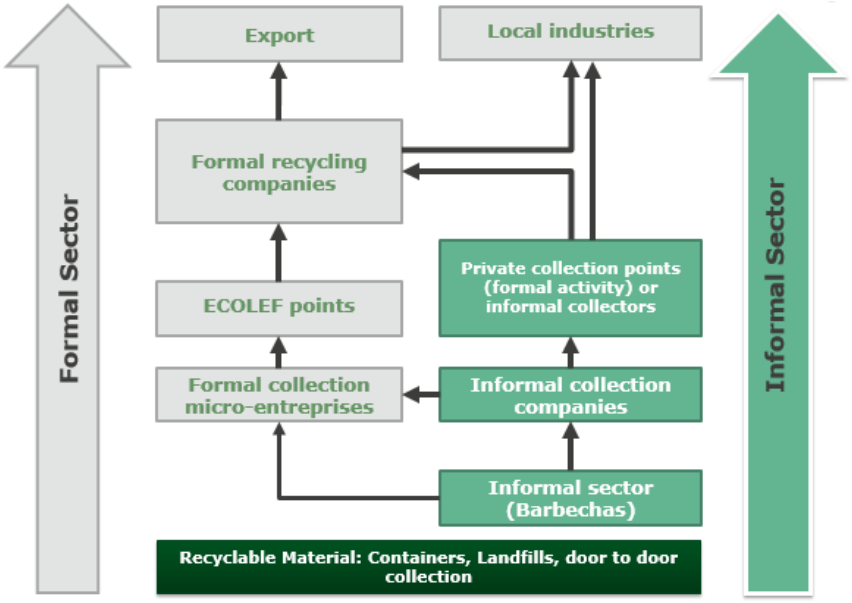

Figure 5-13. *Material flow and role of the informal sector of the actual state*

Informal waste collectors are not visible in the current ECO-Lef system despite the significant contribution in preserving the ecosystem and ensuring a sustainable development. The involvement of the informal collectors into the Tunisian economy could be of great help to this population, mainly on the social, health, economic and environmental levels, as well as for the economy of the country.

The role of waste pickers has become more significant since the Tunisian government opened the SWM sector to private sector participation in 2001 for waste collection activities, sorting and recycling. “Barbechas” depend mainly on the sale of secondary materials extracted from the waste stream to intermediate brokers. These latter are able

to obtain low prices, a quarter (or less) of the physical value practiced at the top of the value chain.

Recyclable waste generated by households, supermarkets and buildings is collected mainly by waste pickers or the informal sector. The latter are also active in landfills to collect the remaining recyclable materials collected by municipalities.

Two possibilities are in question for "Barbechas":

- Selling the collected quantities to private collectors or informal collectors, and then to recyclers in order to be exported.
- Selling to private companies (ECO-Lef members) and then to ECO-Lef points (operated by ANGED in collaboration with the local authorities) where it will be sorted and baled in order to redistribute them equitably to 'conventional recyclers'. Private companies (private ECO-Lef points) can sell to other private sector agents. Recycling centres form the final chain link of the ECO-Lef system. Plastic packaging will either be recycled locally in Tunisia or processed into pellets for export.

"Barbechas" currently cannot directly access the collection points managed by ECO-Lef, which are open only to holders of commercial licenses and who also have to be approved by ANGED. In consequence, the majority of the "Barbechas" cannot benefit from the high price guaranteed by ECO-Lef and are therefore obliged to use intermediaries offering lower prices.

COSTS AND FINANCING OF ECO-LEF SYSTEM

ECO-Tax

The Eco-Lef programme is governed by a decree that specifies the modalities for the collection and management of packaging waste. The programme is partly financed by the private sector through an eco-tax (5% on the net benefit of certain locally manufactured or imported plastic polymers). ANGED is responsible for administering the ECO-Lef programme. All taxes collected are deposited in a fund called the Depollution Fund (FODEP) to which was added the mission to finance the ECO-Lef system (from 2002).

The Finance Law (2004) fixed an expansion of the area of intervention of FODEP and increased the eco-tax from 2.5% to 5% of the turnover. The eco-tax has to be paid by for imported plastic (including empty packaging and raw materials).

In addition to this, the FODEP is a special fund of the treasury created under the law N° 92/122 of December 29th, 1992. The conditions and methods of intervention of the FODEP are set by the decree N° 2005-2636 of September 24th, 2005, modifying and completing the decree N° 93/2120 of October 25th, 1993, and also by the law N° 96/41 of the 10 June, 1996, on waste management.

The FODEP's main tasks are:

- To encourage companies to carry out projects aimed at protecting the environment against the pollution caused by their activities, or to encourage them to set up projects

to rehabilitate and improve the purification performance of existing depollution installations;

- To strengthen the curative aspect by encouraging, through appropriate financing, the use of clean and non-polluting technologies;
- To support the national effort to upgrade businesses.

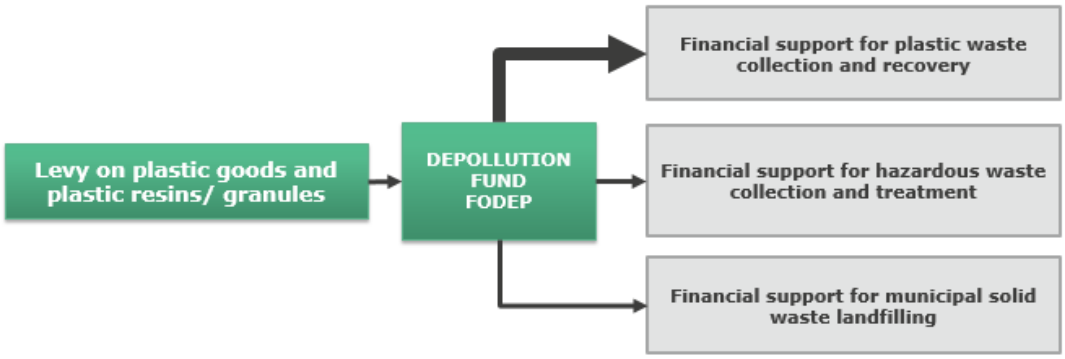

Figure 5-14. *Role of FODEP of the actual state*

The fund collected via the eco-tax is used to finance the ECO-lef system, to cover part of the operation fees of municipal and hazardous waste infrastructures and also some functional costs of ANGED. It is from these funds that the government supports up to 80% of the operating expenses of the controlled landfills against 20% financed by the local authorities.

Voluntary contribution for ECO-Lef

The article 5 of decree N° 97-1102 of 2 June, 1997, fixed the conditions and arrangements for taking back and managing the packaging bags and used packaging. Companies that market packaged products are required to choose one of these options:

- To recover the packaging and have to take care of the management of the used packaging places on the market;
- To entrust this task to an authorised company;
- To adhere to the public system of recovery of used packaging.

The basic principle is that the contribution pays for the packaging, which is not covered by the eco-tax. The sign (logo) and the registration number of the system must be marked on the packaging clearly.

The contribution was calculated according to the nature of the packaging material, and its value is determined for companies who are not subject to the payment of raw plastic imports such as plastic (0.2 TND/kg), tin-plate (0.05 TND/kg), aluminium (0.15 TND/kg) and complex cardboard (0.25 TND/kg).

It was concluded, after a period, that the cost of recovery based on the contribution was very low. At the moment, no system for contribution for plastic producers exists, since the contribution of the marketer and manufacturer is covered at source, and with 5% of

the importation turnover instead of 2.5% for the FODEP. On the other hand, the system of voluntary contribution for other products is kept, but with very limited effectiveness.

Revenues and costs of the ECO-Lef system

The ECO-Lef system is mainly financed by the FODEP. A part of the system is financed by the voluntary contributions of the producers and from the revenues from selling products to recyclers.

To get the necessary fund from the Ministry of Finance, ANGED proposes a budget following an activity plan and the planned recyclable materials quantities to be collected. The Ministry of Finance allocates the budget based on the collected quantities by ECO-Lef points. The system needs different costs that are related to the investments costs, operation costs and management expenses.

5.2.2.2. IDENTIFIED GAPS OF THE CURRENT ECO-LEF SYSTEM

There are many reasons for the optimisation of the ECO-Lef system; these include:

- The payment for collection is not flexible enough according to either the needs of the collectors and the recyclers, and the evolution of the price of the recyclables;
- The contracting partners that are not member of ECO-Lef system (producers for example) are not obliged to deliver a certain fee. This means the contributions are voluntary and no controls exist;
- The incoming quantities of the total collected material amount at national level cannot be calculated. Data is only available on the collected quantities under ECO-Lef. Other quantities are collected by private formal and informal companies;
- There is a lack of accurate data on packaging put on the Tunisian market by the producers and importers;
- The national system, ECO-Lef, is only important for the collectors when offered prices by the private decrease. In addition, ECO-Lef only accepts material with value (important and positive market price) such as foils, bags and PET-beverage bottles;
- Waste pickers, estimated at between 10,000 and 15,000 in Tunisia, collect around 80% of the total packaging collected without being in the system. They only collect materials with positive market value such as PET and cans;
- The cost for waste collection and disposal is the responsibility of municipalities, and the financing is uncertain;
- Littering is still a relevant and visible problem everywhere and the tourism sector is affected by the visual pollution, especially on beaches;
- Consumers are not obliged to follow a specific separate collection system, since they are not part of the system and their responsibilities within the system are not clear;
- A lack of incentive for innovation or to expand the recycling industry in Tunisia.

On the collection level, barriers are related mainly to the market of the collected materials. Most of the recyclables are marketed outside of ECO-Lef, for the private sector which is not a member of the system, which offers a better price to “Barbechas”.

In some cases, problems are related to the inability of some ECO-Lef points to accept the collected quantities due to the incongruence between the number of workers per point and the received quantities. In addition, after the revolution, municipalities asked to get back their sites (ECO-Lef points), without proposing any alternative. Furthermore, there is an absence of a structured manual and of an IT registration system (for the acceptance and the distribution of the quantities) to organise the system. Currently, the management of the collected quantities and its distribution is performed manually. Furthermore, the absence of follow-up and control of the system represents a weak spot in the development of the system. At the central level, the lack of human resources is considered to be a barrier to performing all the requested tasks.

At the recycling level, the collected quantities in 2017 declined which caused many complaints from the recycling companies contracted with ANGED. The distance also represents a barrier for the transport of the stored quantities in some ECO-Lef points by the recycling companies, such as those in Medenine in the south of the country. The transportation of the material costs money and makes the business unprofitable. Finally, the proliferation of unapproved recycling companies (informal recycling companies) represents a barrier facing the sustainability of small formal companies.

Securing long-term financing for SWM measures is the most important basis for investment in the field of SWM. This especially applies to the construction and use of the required collection logistics as well as the construction and operation of facilities. Since the existing ECO-Lef system in Tunisia is insufficient and does not reach the goals, alternative forms of organisation and financing are needed. The optimisation of the ECO-Lef system can have several positive outcomes such as reducing the burden on the public budget, contributing to job creation, reducing waste disposal (landfill) and increasing recycling.

In addition, fee-modulation can increase reuse and recycling, packaging optimisation and prevention. For example, fees and the calculation methods that underpin them have significant potential to influence product design. Further, the implementation of EPR schemes can promote technological and organisational progress and support the development of markets for secondary raw materials, which in turn creates new economic opportunities. Furthermore, recycling reduces CO_2-emissions along with water and energy consumption, which represents an important contribution in a future circular economy. Financially, full cost coverage of EPR can be achieved by ensuring that the fees are paid by producers to cover all the costs of collecting, sorting and processing packaging waste.

5.2.2.3. POSSIBLE SCENARIO OF FUTURE EPR SYSTEM IN TUNISIA

Creation of a new system operator: A new system operator (to be called NOS) needs to be established particularly for packaging waste from households. The system operator should also cover other industrial and commercial packaging waste, where specific targets and reporting should be considered. All types of packaging in the chosen category (e.g., all packaging sold to private consumers and perhaps the defined similar final user, no

matter what material or size) should take part in the system, even if there is no collection or recycling yet. Otherwise, the production of recyclables by the industries would be rewarded by not paying a fee. There has to be an exact definition and, as a support, a list for the correct assignment.

A single organisation, as a not-for-profit organisation, is selected by the actors in Tunisia. The operator will be in the hand of the obligated companies. They are founders and members by contracts and paying fees. The other companies in the supply chain could become shareholders or members on a voluntary level or could be involved as guarantors for recycling of their specific material. The NOS should follow, as part of its purpose, a public service mission regarding the collection, recovery and recycling of household waste.

New mission of ANGED: The agency is actually taking on the responsibility of the operator for the current ECO-Lef system. In the new system, the system operator will ensure this responsibility. However, ANGED will control and monitor the NOS and the progress of the mission. It should also define the objectives in terms of collected materials, recycled materials, recycling rate, etc. These objectives should be based on the existing infrastructure and means, taking into consideration the generated packaging at national level. The agency could also take part as a partner in elaborating the contracts between the system operator and private collection and recycling companies. Indeed, it represents the main guarantee of the collection and recycling companies, whose are afraid of the change of the system.

In addition, both ANGED and NOS should exchange information and documents about the system in order to avoid the double payment of the producers and importers, and to ensure the monitoring of the system.

Responsible producers: The interface for the responsible producer should be defined exactly so that no focused packaging falls out of the EPR-system and a clear identification should be fixed. Obligated companies are those that are the first in the supply chain in Tunisia to put the packed goods on the market. These goods are used in Tunisia, where packaging is most likely disposed. The following companies have to finance the EPR system and to pay the fees:

- Producer/filler for the sale of their packed goods in Tunisia;
- Importer of the packed goods in Tunisia.

In some countries, an exemption for producers, fillers and importers who put a smaller amount of packaging on the national market is taken into consideration and is defined. In the case of Tunisia, it was agreed that stakeholders will not exempt small producers of paying to avoid the free-riders risk. Figure 5-15 summarizes the proposed scenario:

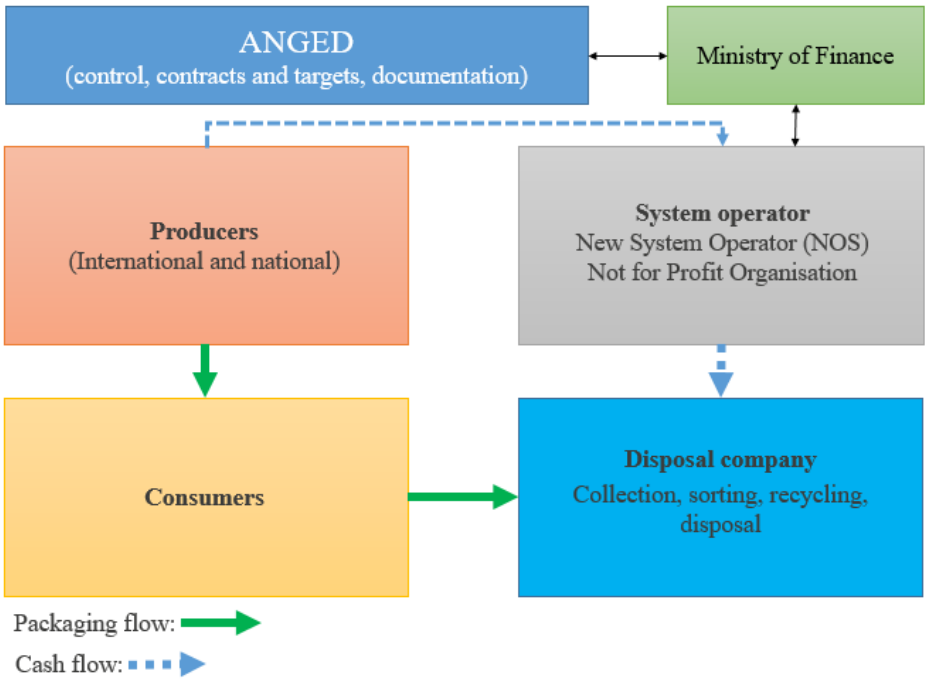

Figure 5-15. *Proposed EPR scheme for Tunisia*

Registration of the producers: The obliged producers should not gain an unfair advantage over their competitors or avoid their responsibilities by choosing one of the other of these mechanisms. Registration, surveillance and a detailed reporting system must be established to ensure the transparency of the system.

Costs of the SWM operations: The SWM fees should be calculated based on the net costs of collection, sorting and recycling in relation to the respective material (full cost responsibility). In addition, it should include further costs such as awareness campaigns and other defined tasks. The fees should be transparent and publicly available, especially in cases of a monopoly. The fee for each obliged company should be calculated based on the amount and type of packaging-material put on the Tunisian market. Furthermore, the fees should implement an incentive to invest in green product design. For example, actual recyclability of the packaging should be taken into account in the pricing.

Collection system within the new EPR concept: Sorting at source is a necessary step to implementing an EPR system for packaging in Tunisia. Through sorting at source, the responsibility for the collection of the mixed waste, which is currently ensured by the municipality, is shared with private sorting and recycling companies (recyclable material).

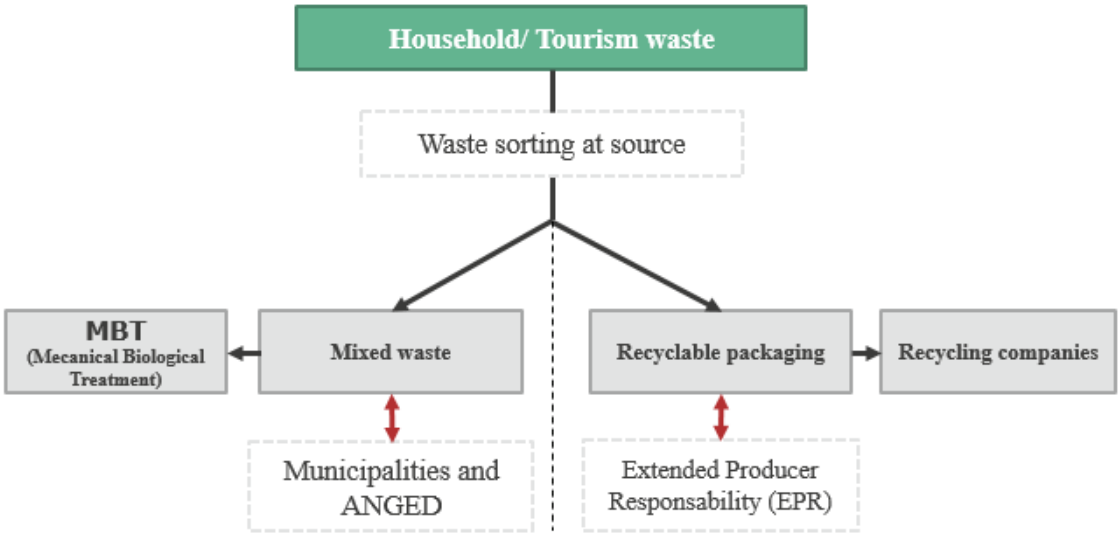

Figure. *Proposed collection system within the EPR model*

Currently, municipalities in Tunisia lack experience and expertise, and the infrastructure required to support sorting at source is limited. This operation would reduce the pressure on municipalities (costs, logistics, human resources, and space) and create new opportunities (jobs, businesses and EPR system development).

A decision has to be made as to whether separate collections shall be available nationwide, perhaps in different types of collection systems and in defined steps. At the very least, the system operator should demonstrate, through an SWM plan along a timeline, the steps that will be taken to reach this goal. The collection points under the ECO-Lef should be integrated into the new collection system. A bring-it-yourself system could be combined with door-to-door collection projects. Anyone who is allowed to use this separate system should also ensure that the recycling targets are only achieved with the packaging allocated to the NOS.

Informal sector involvement: "Barbechas" are contributing considerably in the collection of recyclable materials in Tunisia. Potentially, "Barbechas" could organise themselves through associations, which could become contractors with the NOS. Further, the involvement of the informal sector in the official system, through the education and their registration in the national social security system could improve their social and economic conditions. This will allow them also to apply for small credits. The involvement of this important actor is considered the key factor of the success of the EPR system in Tunisia.

Role of the municipalities: The role of the municipality and the need for coordination with the NOS should be defined in the packaging law. Since municipalities in Tunisia are very differently equipped and the necessary services in the waste management cannot be provided in the same way, it is recommended that the task of the collection of packaging is basically organised by the operator. There could be an obligation to contract with a municipality if they can prove they are able to provide the services (on a standardised cost level), or the municipalities could take part in a call for tender, like the private companies.

Municipalities and the system operator could also co-operate with civil society in local public communication and awareness programmes. Its mission covers also the establishment of a clear and strong plan to ensure cleaning beaches services.

A calculation of the possible revenues from this system has been estimated. Considering that a German citizen contribute with around 15 Euros per year to the EPR system, indirectly through baying different packaging products, and considering that the average gross salary in Germany is three times more the salary in Tunisia, it could be estimated that a Tunisian citizen can contribute with 5 Euros per year to the EPR system, and a total of 57 million Euros per year.

5.2.3. RECOMMENDATIONS

Following the activities of this project and the literature from international experiences, several lessons were learned when establishing an EPR concept in Tunisia. Firstly. It is important to ensure a strong governmental involvement to enforce a level playing field and to enforce environmental standards and targets. In addition, a strong reporting and monitoring system for the EPR has to be established (for producers, fillers and importers, collectors and recyclers).

Furthermore, the system should ensure that the EPR system can be financed in a sustainable manner, which represents one of the principals of the concept. Transparency is absolute necessary for effective government oversight. Indeed, the register of producers, official accreditation of producer responsibility organisations should be implemented for all-concerned companies. The fees should be paid by the amount (weight) of specific material put on the market. However, free-riding represents a challenge to many EPR systems and should be addressed by strict enforcement. Otherwise, the performance of EPR operations should be regularly audited, preferably independently, and appropriate sanctions are to be defined by the law.

It is also to be noted that, in the framework of the EPR system, the collection and recycling targets should be fixed and periodically reviewed and adjusted according to the changes in market conditions and technology and the change of the status of the system.

In addition, a clear definition of the scope of the EPR (what kind of packaging, who is obliged, etc.) should be developed, as well as the responsibilities. Further, the role of the municipality must be well defined as a potential waste management service provider.

Further, relevant factors include contract duration and recovery of costs. Most attention should be placed on competition issues in product markets, where the welfare effects are potentially largest; this should be followed by collection and sorting markets, recovery and disposal markets, and the market of producer responsibility services. Furthermore, it is recommended that services such as waste collection, sorting, and material recovery and disposal be procured by transparent, non-discriminatory and competitive tenders.

Ideally, producer responsibility would be implemented at the level of individual producers; however, most EPR systems apply producer responsibility, which dilutes incentives for eco-design. Where possible, producers' fees should, therefore, be more

closely linked to the actual end-of life treatment costs of their products; for instance, through the use of variable (e.g., weight-based) rather than fixed (e.g., unit-based) fees, and/or modulated fees that differ according to specific design features that make products more easily recyclable.

Finally, an EPR system needs to find ways for informal operators to work with rather than against the system, unless there is a risk that they will be undermined by them.

5.2.4. CONCLUSION

To ensure a fruitful SWM system in tourism destinations in Tunisia, a collective effort from all concerned parties is required. Such a system should consider economic, social and environmental aspects. To achieve this target, an integrated approach should be considered. Integrated thinking for the recovery of materials is the key to a SWM system that can transform the waste in the tourism sector from being the source of environmental issues to becoming a solution. In the new model, both national and local stakeholders should be instrumental to improving the cleanliness of their cities and sharing the pressure. The position of local society and industries in this model is considered to be both a public service customer and an active public service partner.

Developing an EPR concept could play an important and key role in addressing waste problems and in setting up recycling structures in Tunisia. The concept of EPR is a policy principle designed to promote the environmental improvement of products and manufacturing systems (Herdiana et al., 2014). The foundation of an EPR system in Tunisia must be defined by law. This legal framework must consider the current situation as well as the specified objectives, which should be attained by an EPR system for the packaging market and in relation to the disposal of packaging.

The different situations and very different political objectives in individual countries means that every law and every EPR system is also different. Individual elements can be compared; however, even best practice recommendations can only be formulated under a specific objective. Thus, the following principles should be applied when designing and implementing EPR systems:

- The provisions in the law must be unambiguous and must be implementable;
- The obligated parties and their obligations must be clearly stated and specifically identifiable;
- The execution must be regulated so that the obligated parties cannot withdraw;
- Clear regulations must be provided for all areas, in particular, for monitoring and execution.
- All areas of decision making must be discussed politically, be socially acceptable, feasible to implement, and economically and ecologically sound. This challenge requires fundamental preparation and discussion with all stakeholders.

This research has shown that the development of an EPR system should be based on a participative approach including different stakeholders. Negotiations will guide the working team to select the concepts that fit best with the national and local situation. An

EPR system should be adapted to the situation of each country and its specific characteristics. The optimisation of, or change to, an existing system always remains a difficult task since it requires an optimisation on different levels, such as re-thinking, laws, organizations, etc. In addition, an EPR should be implemented through clear legislation and should create good-working cooperation between governments, producers and waste management organisations.

The EPR solution comes to confirm the organizational solution of chapter (5.1), and to support financially the current SWM system in Tunisia, which is suffering several difficulties in the framework of the decentralisation. The clarification of the responsibilities and the involvement of the producer of packaging in the system will definitely lead to achieve the planned goals of recycling, and to ensure clean destinations, that satisfy visitors and tourists during the year.

However, establishing an EPR concept in Tunisia can indirectly support the composting of bio and green waste, through the establishment of a correct organisation and an appropriate legal framework to sorting at source the generated waste from households and hotels. These clean biological fractions could be valorised through the establishment of the composting process.

5.3. THE POTENTIAL OF COMPOSTING OF ORGANIC MATERIALS IN TOURISM AREAS

Composting is an important method of solid waste treatment that contributes to reducing organic waste destined to landfill disposal or incineration (Storino et al., 2016) and, in consequence, reducing CO_2 emissions in the environment. This treatment method remains the most common means of organic waste recycling worldwide. It is defined as the aerobic biological decomposition and stabilisation of organic fractions, under conditions that allow the increase of temperatures as a result of biologically produced heat, to obtain a final stable product, free of pathogens and viable plant seeds, and which can be favourably applied for agricultural activities (Oazana et al., 2017).

The evolution of the tourism industry in Tunisia must be associated with good organisation and management of the large amounts of solid waste generated, especially the organic fraction, which represents 63% of the total fractions. Hotels, as tourism establishments, generate significant amounts of bio-waste (representing, for instance, 58% of the waste from hotels in Gammarth and Hammamet: see Figure 4-2). Another detailed sorting analyses realised in the framework of this research in some tourism municipalities (Table 4-2 and Table 5-5) showed the presence of 49% organic waste in Bardo, 24% in Sidi Bousaid and 55% from hotels in the Hammamet tourism municipality, in which vegetable waste and green waste represents the main fractions. Green waste also represents a substantial problem in most tourist destinations, since there is no clear concept to manage it, and it is collected and landfilled by the authorities. For instance, green waste generation is estimated to be 2,537 tons in the municipality of La Marsa and 2,000 tons in Bizerte.

To overcome this, effective strategies for managing this type of waste should be adopted. Among the several waste treatment options currently available worldwide, composting remains the most widespread method of organic waste recycling (Onwosi et al., 2017).

Recently, there has been increased interest in Tunisian society in the local treatment and use of organic residuals that have been used as soil conditioners and plant supporters. To this end, this research presents the findings of the first small-scale application of source-separated bio-waste (kitchen and green waste) composting in Tunisia. The aim of this work was to monitor and analyse the operating parameters in an aerobic composting process of bio-waste generated from Gammarth tourism destination as well as to evaluate the quality of compost products that can be obtained in practice by implementing a windrow composting approach in comparison with the Tunisian and German established quality standards.

5.3.1. MATERIALS AND METHODS

5.3.1.1. STUDY AREA

Gammarth, in the northern suburbs of Tunis, close to La Marsa (Figure 5-17), is famous for its five-star hotels and nightclubs, as well as its beaches, magnificent forest and a nice

view of the sea (Khalifi, 2018). Tourism is now the strength of the local economy as hotels dominate the coastal zone, which attracts tourist, national and business visitors.

The research experiments were conducted on an established composting pilot plant located in the area, in a landfill site located around 20 km from the centre of Tunis. The pilot composting project was built by the municipality of La Marsa in 2017.

Figure 5-16. *The municipality of La Marsa: Gammarth tourism zone (red) and the composting plant (yellow).*

The municipality of La Marsa is characterised by its high vegetation cover and the abundance of private green spaces and gardens. This is a reason for the municipality to dedicate a special service to the daily collection of green waste, whether from public spaces or private gardens.

In the absence of a quantification system for this waste, an estimate was made based on the number of trips per area, the capacity of the tractors used and the density of the green waste. Table 5-7 shows the collection process and the quantities of green waste collection in La Marsa.

In addition, a sorting analyses of waste was performed in four hotels in Gammarth. It was found that about 39% of the waste was from food preparation, 59% from guests' plates, and 2% from non-consumed food. Furthermore, the characterisation of the kitchen waste in these establishments showed that 83% of the generated waste was bio-waste. The remaining 17% included paper (6%), plastic (5%), glass (3%) and metal (3%). These results confirm the importance of establishing a composting experience for green and clean kitchen bio-waste to reduce the amounts of organic waste landfilled and, in consequence, reducing treatment costs and CO_2 emissions.

Table 5-7. *Green waste generation in La Marsa/Gammarth tourism destination.*

Zone	Collection vehicle	Vehicle volume m^3	Trip/ day	Working days/year	Vol of waste m^3/year	Density	Amount Ton/year
Corniche	Tractor	3	2	358.5	2151	0.15	323
Marsa Coup	Tractor	3	2	358.5	2151	0.15	323
Cité Hokkem	Tractor	3	2	358.5	2151	0.15	323
Cité Nassim Cité Wifek	Tractor	3	2	358.5	2151	0.15	323
Cité Sid Daoued	Tractor	3	2	306.5	1839	0.15	276
Cité Gammarth Cité Habib	Tractor	3	2	358.5	2151	0.15	323
Cité Khalil Cité Mothabra Cité Tabek	Tractor	3	2	358.5	2151	0.15	323
Corniche Marsa plage Tayeb Mhiri	Tractor	3	2	358.5	2151	0.15	323
Total of green waste generated in La Marsa							**2537**

5.3.1.2. RAW MATERIALS AND METHODOLOGY

Two different windrows were established in the same period comprised of a communal bio-waste consisting of source-separated organic waste: kitchen waste from hotels (fruit, vegetable) and green waste. The different organic raw materials were blended together in certain ratios by gently mixing bulking agents (tree clippings and 10% sawdust) to provide the required carbon/nitrogen (C/N) ratio needed for efficient decomposition. Once the raw materials were prepared for composting, and after mixing had been completed, suitable conditions for starting rapid aerobic composting (moisture and aeration) were supplied. The two different types of compost were obtained by mixing clean kitchen bio-waste from Gammarth's hotels and plant residues at the following different ratios:

- Compost 1 (C1): Green waste (100:0)
- Compost 2 (C2): Clean kitchen waste and green waste (70:30)

The compost 1 aims the test of the applicability of the composting process for tourism municipalities generating high green waste amounts. The compost 2 aims the assessment of the feasibility of the composting of organic waste (clean vegetable waste), with the addition of 30% of green waste, principally of grass, to adjust the C/N ratio.

For the green waste: After the collection of green waste by the municipality of La Marsa, the fraction was sorted to eliminate plastic waste and other types of undesirable waste. After that, the grinding of the waste was performed to increase the attack surface for the decomposing microorganisms and to reduce the volume of the raw materials. For the kitchen organic waste: The collection of organic waste was made from four hotels in

Gammarth tourist area. This fraction was completely clean and did not contain undesirable products, which could affect the composting process.

The prepared mixtures were aligned in long windrow piles. Each one had a triangle-shaped profile (2.5 m high, 4 m wide, and 20 m long). During the composting process, the piles were turned mechanically using a windrow turner, with a frequency of two times per week, while respecting the evolution of the temperature (T> 60° C) mainly during the mesophilic and thermophilic phases. The raw materials were mixed at different component ratios to adjust the initial C/N ratios. Water was added to provide optimum moisture, which is important to optimise the microorganism function during the composting process.

After that, the windrow piles were mechanically turned according to a periodic schedule, to maintain effective aerobic decomposition. Direct in-situ measurements of temperature, moisture, C/N and pH were frequently monitored during the composting process. Sampling was conducted to represent different stages of the operation. Respiration activity analysis (AT4) and the measurement of concentrations of heavy metal were also carried out. The characteristics of the initial raw materials used in our case are presented in Table 5-8. After the preparation of the raw materials, they were sorted, screened and shredded, and then mixed to maintain good conditions for the operation (nutrient content and bulk porosity).

Table 5-8. *Initial characteristics of the raw materials.*

Parameters		**Green waste**	**Kitchen waste**
pH		6.5	5.83
Temperature °C		28	29
COT (g/kg MS)		520	594
NTK (g/kg MS)		14.44	18.38
C/N (g/kg MS)		36.01	33.56
MO (g/kg MS)		742.78	805.21
Salinity (MS/cm)		2.09	3
Density (g/cm^3)		0.45	0.51
Mineral elements	CaO (g/kg MS)	52.43	71.86
	MgO (g/kg MS)	2.59	2.77
	K2O (g/kg MS)	9.72	11.66
	P2O5 (g/kg MS)	2.15	2.29
	Na (g/kg MS)	1.57	1.82
Trace metals	Se (mg/kg MS)	<0.05	<0.05
	Sb (mg/kg MS)	0.77	0.76
	As (mg/kg MS)	<0.05	0.10
	Sn (mg/kg MS)	<0.05	<0.05
	Hg (mg/kg MS)	0.64	0.57

Compost samples were taken at the end of the operation to determine the chemical, physical and microbiological properties. Each sample was constructed by mixing ten subsamples taken from ten points in the pile. These were then placed in polyethylene bags

and transferred to the laboratory for analysis. Analyses were realised within the CITET and Rostock University's laboratories.

5.3.2. Results and Discussions

5.3.2.1. TEMPERATURE

Compost pile temperatures were measured continuously on site (Figure 5-18). The temperatures in all piles were found to be above 50°C for the first fifteen weeks of composting (active phase). The second phase of composting (curing phase) exhibited an escalating temperature decrease, indicating that the pile contained more stabilised organic matter; consequently, the microbial activities and decomposition rate declined and the temperature gradually fell to an ambient level, marking the end of the active phase. Within the first three and fourth weeks of the C2 and C1 respectively, the temperature rose above 55°C and reached approximately 65°C within six weeks for C2 (thermophilic phase). Thereafter, the temperature declined slightly to around 55°C and then remained above 50°C between weeks thirteen (C2) and fourteen (C1); it then dropped further during the second phase of composting (curing phase). All piles had an active thermophilic phase of more than five consecutive weeks that ensured the thermal destruction of pathogens and weed seeds. The decline in temperature to ambient levels was clearly shown in the last weeks. This was because the microbial activities and decomposition rate declined, thus indicating that the maturation process of organic materials and the conversion of compost material into biologically stabilised products had been efficiently completed.

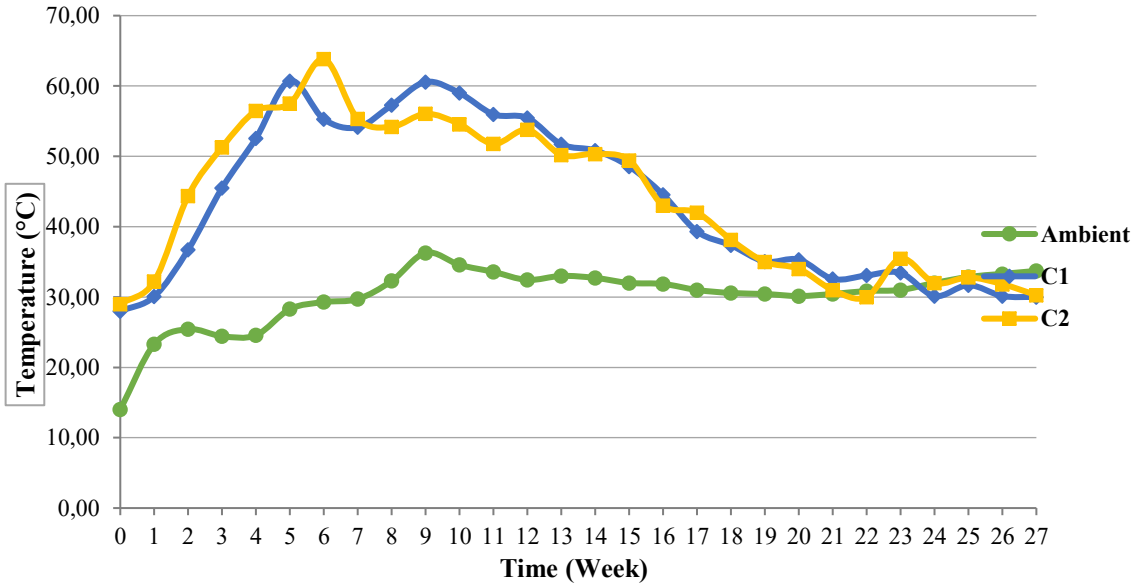

Figure 5-17. *Temperature evolution during the composting process*

5.3.2.2.pH

The pH value of the compost is important because applying compost to soil can change the pH of the soil, which can affect the availability of nutrients to plants (CIWMB, 2007; USCC, 2001). The pH is a measure of the active acidity in the feedstock or compost and most finished compost will have pH values ranging from 6 to 8; these ranges may

substantially differ depending on the kinds of feedstock used. Microorganism growth and gaseous loss of ammonia are influenced by variations in pH during composting; therefore, the optimum pH for microbes involved in decomposition lies between 6.5 and 7.5 (Rynk et al., 1992).

After a possible initial drop, which most likely occurred during the first two weeks of composting (CIWMB, 2007), the changes in pH presented in Figure 5.19 appear to be in qualitative agreement with the typically expected pH-time profile of the composting process. In particular, the experimental windrow piles exhibited a similar temporal sequence with a phase of increasing pH followed by a decreasing phase (although with a final increased value in the sixth week).

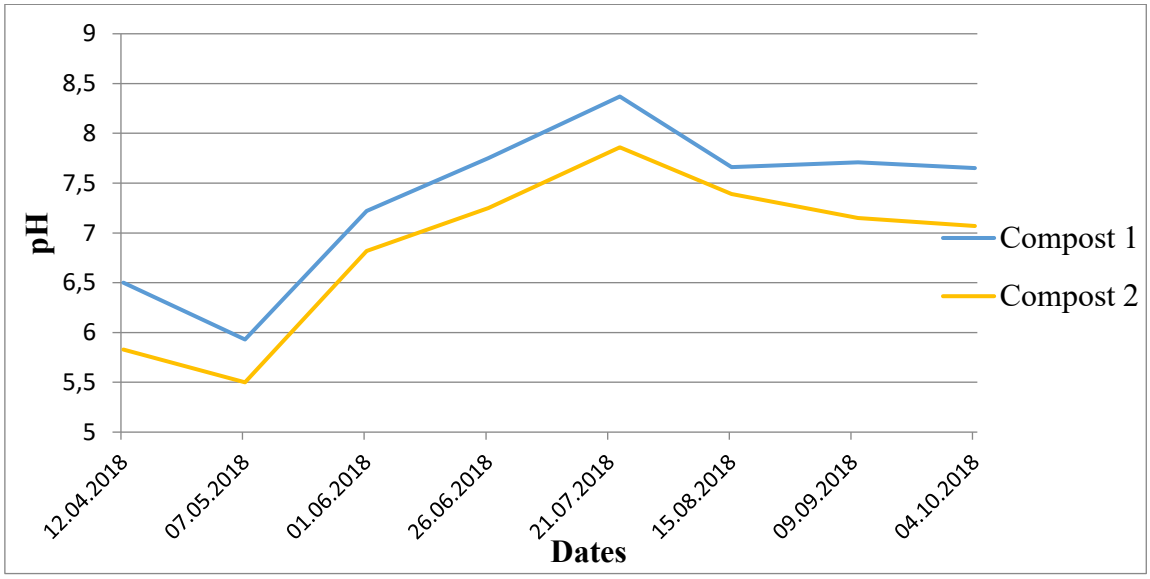

Figure 5-18. *pH evolution during the composting process for C1 and C2.*

The pH profiles of the pile materials during the four runs are shown in Figure 5-19. This shows there was a decrease in pH during the first five weeks of composting and that the pH of decomposition lay between 5.5 and 6.0. The decrease in pH values is attributed to the biological activities of aerobic decomposition, which produces hydrogen atoms: acid (Poincelet, 1977).

Despite the high rate of biological activity during the initial phase of composting, pH values were never less than 5.5. This can be explained by the high buffering capacity of the composting material, which prevents an acute decrease in pH values (Willson, 1993). As the composting process progressed, pH values increased up to 8.3, and had generally stabilised between 7.0 and 7.7 by the end of the second composting phase for C1 and C2, respectively. This pH range is within the optimum range for growing media, which, according to Bunt (1988), is from 5.2 to 7.5.

5.3.2.3. C/N RATIO

The C/N ratio plays a significant role in the nutrient balance in a composting mixture, indicating the amount of carbon available, in relation to nitrogen, for the composting microorganisms.

In this study, the two piles had different initial C/N ratios. These ranged from 33 to 36 across all the piles, which exhibited similar C/N ratio reduction profiles and trends (Figure 5-20). The C/N ratio clearly decreased by the end of composting process. The final C/N ratio ranged from 11 to 13. The lowest C/N ratio (11) was found for C1 and the highest (13) was found for C2. The C/N ratio of matured compost has been reported to be less than 20 (Hemidat et al., 2017). The results of this study showed the C/N ratio to be lower than 20 in the two piles, thus indicating the final compost to be a mature compost. The highest reduction of C/N ratio took place in the C1 pile, where a reduction of more than 55% was achieved. This high level of reduction can be attributed to the degradation process, as well as the low initial C/N ratio (Abbassi et al., 2015).

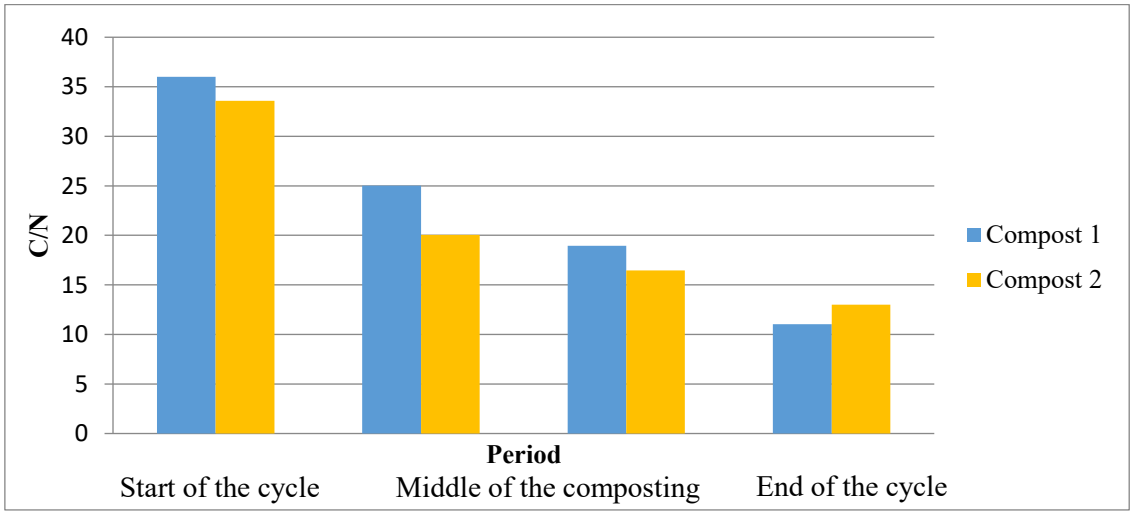

Figure 5-19. *Evolution of C/N ratio during the composting process.*

5.3.2.4. NUTRIENT CONTENT

Temporal evolutions in the experimental windrow piles of extractable nitrogen, phosphorus and potassium have been clearly observed (Table 5-9). Both experimental windrow piles showed increases in measured phosphorus P2O5 and potassium K2O contents in relation to weekly composting time, with final values (by the end of twelve weeks) of 2.85 and 2.97 g/kg MS for P concentrations, and 11.78 and 16.74% for K concentrations, which were exhibited in C1 and C2, respectively. There was an increase in the agriculturally beneficial fertilising elements of phosphorus and potassium. Overall, 33 and 30% increases in P concentrations, and 22 and 44% increases in K concentrations were exhibited in C1 and C2, respectively. These increases were due to the reduction in composting volume and the increase in pile bulk density (Ouédraogo et al., 2001). However, 29% and 35% decreases in the concentration of nitrogen could be explained by the losses of N through NH_3 high volatilisation at high pH.

Table 5-9. *Contribution in mineral elements of finished compost.*

Parameters (g/kg MS)	C 1		C 2	
	Start of composting cycle	Finished compost	Start of composting cycle	Finished compost
Potassium (K2O)	9.72	11.78	11.66	16.74
Phosphorus (P2 O5)	2.15	2.85	2.29	2.97
Nitrogen (N)	14.44	10.25	18.38	12

5.3.2.5. HEAVY METALS

Heavy metals are trace elements with concentrations that are regulated due to their potential for toxicity towards humans, animals and plants. Many of these elements are actually required for normal plant growth. There are many sources of heavy metals within household waste, several of which can pass through mechanical screens designed to remove non-biodegradable matter such as batteries. High-quality compost should be low in trace elements and soluble salts and should be free of inert contaminants such as stones, plastic, glass and metal. The heavy metal concentrations of the compost sample analysed for this study were compared with the German standards (BioAbfV, 2017). The results of the heavy metals concentrations in the samples are shown in Table 5-10.

Table 5.10. *The contents of metallic trace elements.*

Parameters	Range (Experiments in Germany)	Range (Experiments in CITET-Tunisia)	German standard (BioAbfV, 2017)		Tunisian standard NT 10.44 (2013)
			Class A	Class B	
Pb mg/kg	2.89 – 7.98	2.12 - 3.13	150	100	180
Cd mg/kg	0.03 – 0.15	0.056 – 0.16	1.5	1.0	3
Cr mg/kg	1.55 –3.84	15.27 – 11.94	100	70	120
Cu mg/kg	10.5 –14.55	17.83 – 20.62	100	70	300
Ni mg/kg	1.27 – 3.25	10.82 – 15.47	50	35	60
Hg mg/kg	< 0,08	-	1.0	0.7	2
Zn mg/kg	35.16 – 53.12	25.75 – 31.52	400	300	600

The results show that heavy metals in the composts C1 and C2 were much lower compared to the German standards.

5.3.2.6. BACTERIOLOGICAL PARAMETERS

The main objective of the evaluation of bacteriological parameters is to eliminate any health risks. The microorganisms studied were total and faecal coliforms, streptococcus and Escherichia coli contained in the initial and final compost. From the table below, we observe that the number of microorganisms: *Escherichia coli*, faecal coliforms, total coliforms and *Streptococcus* does not exceed the limits of the Tunisian standard, NT 10.44.

Table 5-11. Bacteriological parameters of composts (CFU/g).

Parameters	C 1		C 2		Standard (NT 10.44)
	Raw material	Finished compost	Raw material	Finished compost	
Total coliforms	$2.1.10^4$	$4.3.10^3$	$4.6.10^4$	$2.3.10^3$	$<10^4$
Faecal coliforms	$2.1.10^5$	$2.3.10^3$	$2.8.10^5$	$9.3.10^3$	
Streptococcus	$9.3.10^3$	$7.4.10^2$	$2.1.10^3$	$1.5.10^3$	
Escherichia coli	$9.3.10^4$	3.10^1	$0.21.10^3$	-	$<10^2$

5.3.2.7. RESPIRATION ACTIVITIES (AT4 TEST)

The respiration activity is related to the metabolic activity of microorganisms. Their respiration at higher rates is related to the presence of large amounts of bioavailable organic matter, but it is slower if this type of material is insufficient. The measurement of the respiration activity has become an important parameter for determining the stability of the compost at the end of the composting process. It could also be used to monitor the process and is an essential factor when estimating the maturity of the material (Komilis & Ham, 2003).

The maturity of the final compost is considered an important factor to ensure successful agricultural use. However, an incomplete or immature compost product indicates that microbial activity could be the source of bad effects (Garcia et al., 1992). As compost has traditionally been used agriculturally, this implies that plant growth will be negatively impacted. Therefore, mature compost will exhibit characteristics that indicate the completeness of the composting process. The stability of any given compost is important in determining the potential impact of the material on nitrogen availability in soil. Most uses of compost require a stable to very stable product that will prevent nutrient tie-up and maintain or enhance oxygen availability in soil. As Table 5-12 shows, compost respiration in the samples varied from 4.2 to 8.7 mgO2/g dm; accordingly, all the compost samples appeared to be stable, and thus can be rated as IV and V finished products.

Table 5-12. *Classification of the compost samples analysed for the AT4 test.*

Rotting class (BioAbfV, 2017)	AT4 (mg O2/g DM)	Classification of the tested samples	Product description
I	>40	0 %	Compost raw materials
II	40-28	0 %	Fresh compost
III	28-16	0 %	Fresh compost
IV	16-6	50 %	Finished compost
V	<6	50 %	Finished compost

The results indicate that the compost produced was stable and the biological activity had stopped. This shows that the organic material had been destroyed to form a new stable material (soil) that could be used for agricultural purposes. It also indicates that the compost production process was performed successfully and under ideal conditions.

5.3.3. CONCLUSION

Despite the organic fraction representing 63.2% of the total waste generated in Tunisia (2.8 million tons produced in 2017), only 1-2% of municipal waste is currently biologically treated in Tunisia. Tourism destinations generate large amounts of bio-waste, which is landfilled in most cases. This study investigated the physicochemical properties of compost made of different segregated bio-waste raw materials (green waste and clean kitchen waste) in the tourist destination of Gammarth. To this end, two experimental windrow piles were initiated and monitored. The first containing 100% green waste, and the second composing 70% clean kitchen waste and 30% green waste. The windrows needed 24 and 25 weeks to complete the composting phases and produce stabilised products. The monitored experimental process showed overall decreasing profiles versus composting time for moisture, organic carbon, nitrogen, carbon/nitrogen content and piles volumes, as well as overall increasing profiles, total phosphorus, total potassium and bulk density, which represented qualitative indications of progress in the process. Final product quality was examined and assessed against the quality specifications of German standards for compost, which has been subjected to composting, aiming to specify whether the different types of organic wastes that have undergone recovery cease to be waste and can be classified as high quality compost. More specifically, final product quality findings showed that concentrations of all seven heavy metals (Pb, Zn, Cu, Cd, Cr, Hg and Ni) were within the set limits and were much lower compared to German standards. The respiration activity test showed that the compost production process was performed successfully and under ideal conditions.

These findings indicate that composting was carried out successfully under optimal conditions. However, the required period to produce high quality finished compost was relatively long due to the composition of substrate. This parameter could be optimised to reduce the processing time, thus reducing the costs for the municipality. The forced aeration could also represent a solution to accelerate the process.

Overall, the composting of source-separated organic materials or green waste provides an effective alternative for tourist destinations in Tunisia. The composting process should be generalised in these zones through the implementation of composting plants. It is considered very beneficial for municipalities and for the country since it is a valuable addition to soil, for agricultural and green spaces, and avoids methane production and leachate formation in landfills. Moreover, municipalities should take the initiative to prohibit green waste landfilling, since it is considered as clean material.

6. DESIGN OF NEW POSSIBLE APPROACHES FOR SWM IN TOURISM AREAS IN TUNISIA

6.1. GENERAL MODEL

Solid waste management in tourism areas needs a specific concept. In large tourism destinations, waste generated doubles the local waste production, which creates financial and logistical pressures for the local government in Tunisia. The latter have limited capacities to conduct all waste management activities correctly and to ensure clean tourism zones. A questionnaire, realised within 19 tourism municipalities in Tunisia, showed that municipalities spend between 6.3% to 50% of their budgets on waste collection from hotels and households, as tourists, visitors and local residents generate large amounts of solid waste, particularly during high seasons. These costs do not include cleaning activities, which are also expensive. In addition, municipalities have very limited SWM logistics such as collection tracks, available containers and bins on the streets and on beaches, etc. Furthermore, all controlled landfilling in the country suffers from a lack of sites. Effective waste management ensures the sustainability of tourism areas and it supports preserving the attraction of the destination. The benefits include also the generating of revenues from the sale of recyclables, developing good community relationships, reduces odours and improves aesthetics and sanitation, and increases tourists' satisfaction.

The design of the general possible concept for tourism destinations in Tunisia, and possible actions for the main activities, are presented in Figure 6-1 and Figure 6-2.

At the moment, the new orientation of the Tunisian Government, represented by the MLAE and its agency "ANGED", is aimed at the recovery and the valorisation of recyclable fractions, and the stabilisation of the organic fraction before landfilling. To do that, the government decided to build 18 MBT plants. This operation requires that previous sorting at the source of the waste must be established from all waste generators, to separate the residual waste from all other packaging and recyclable fractions. Only residual waste will be treated through the MBT. The transport of the collected residual waste to MBTs will be ensured by the municipality, or through a private service provider **(See point A)**.

On the one hand, sorted packaging and recyclable fractions could be the responsibility of the new not-for-profit EPR system operator, NOS **(See point B)**. The latter will be responsible for the financing and the organisation of the SWM activities. It could be financed by the producer, the importers and fillers of goods in Tunisia according to the quantities of products put into the market. Further, ANGED could control and monitor the system, as well as fixing collection and recycling objectives to be respected by the system operator **(See point C)**. To do that, the latter should develop a clear plan to reach the goals in terms of communication, raising awareness and implementing an adequate infrastructure for waste sorting. In tourism destinations, this role could be ensured by the NGOs (developing waste sorting initiatives, raising awareness activities, etc.) and by the

national authorities such as CITET (ensure a training programme for hotels labelling) and ANGED **(See point D)**. On the other hand, the NOS could collaborate with the collection companies and recyclers. This solution could result particularly in the increase of the collected recyclables quantities at the national or exported level; in consequence, it reduces its presence in the landfills and in nature, and could support the local economy **(See point E)**.

From a technical point of view, tourism destinations generate large amounts of organic and green waste from hotels, restaurants, residents and households. These fractions represent a troubling issue to municipalities and to the national authorities, since it increases the collection and treatment costs. It also contributes to CO_2 emissions and the generation of leachate in the landfill. In fact, these types of waste could be valorised and composted if an adequate sorting at source is performed. The main objective of this technical solution is to avoid a problem more than creating revenues from compost. The compost could be used for municipal activities, as well as private (hotels, households, etc.) or agriculture activities in the tourism zone **(See point F)**.

The combination of beach and waste does not make for a good holiday. In Tunisia, were tourism represents one of the main economic activity, solid waste pollution could stay on the beach for a long time, especially during low seasons, thus reducing the touristic value of the otherwise attractive location. Beach cleaning must receive special attention from all actors as it represents the image of the destination. In addition to the manual cleaning actions (aimed at the cleaning of inaccessible points), the existence of automated beach cleaning equipment within tourism municipalities is an important factor to ensure the cleaning actions during the year. Standard SWM programmes have become necessary on Tunisian beaches. The communication and awareness campaigns using various awareness slogans, signs and directives for visitors, local citizens and tourists is necessary. Approaching the sustainability of clean beaches requires the essential elements of participation, political leadership, planning and policy **(See point G)**.

Street and route cleaning, including waste collection and sweeping, represent also a key factor influencing the image of the destination. Since the municipality is in charge of this task in Tunisia, a road-cleaning plan should be developed. This plan should run in parallel with a planned collection from municipal containers and bins installed on the road. The elaboration of the plan should be based on a number of sessions, including all actors in the destination, which leads to the adoption of best ideas and suggestions **(See point G)**.

Otherwise, the cleanliness of the old town, having a high importance in tourism areas in Tunisia, is related to several conditions and activities including the availability of an adequate infrastructure (bins, special tracks for collection, and so on) and the sorting at source from the commercial activities of packaging (paper, cardboard, plastic, and so on), which represents the main fractions. In addition to that, the establishment of awareness programmes and the control of waste generators could play a crucial role to ensure the cleanliness of the area and the recovery of clean packaging waste to be recycled **(See point G)**.

Furthermore, restaurants and hotels are also responsible, as potential waste generators, for ensuring cleanliness and increasing the recycling rate of the generated waste. Waste sorting at source should be enforced by law in these establishments. In addition, the development of an awareness programme for tourism establishments could support the efforts towards reducing the quantities of waste generated at source, and reinforce sorting at source actions. By adopting proper environmental practices and through the marketing of their environmental vision, hotels can enhance their image and attract more attention from tourists who have an awareness of the impact of tourism activities, travel agencies and tour operators. Hotels should also play a relevant role through encouraging eco-labelling in these enterprises. As Masau and Prideaux (2003) indicate, tourists are willing to pay more for environmentally friendly products and services such as accommodation. In contrast, improper waste disposal practices could result in harmful environmental and health impacts, as well as a poor image for the destination.

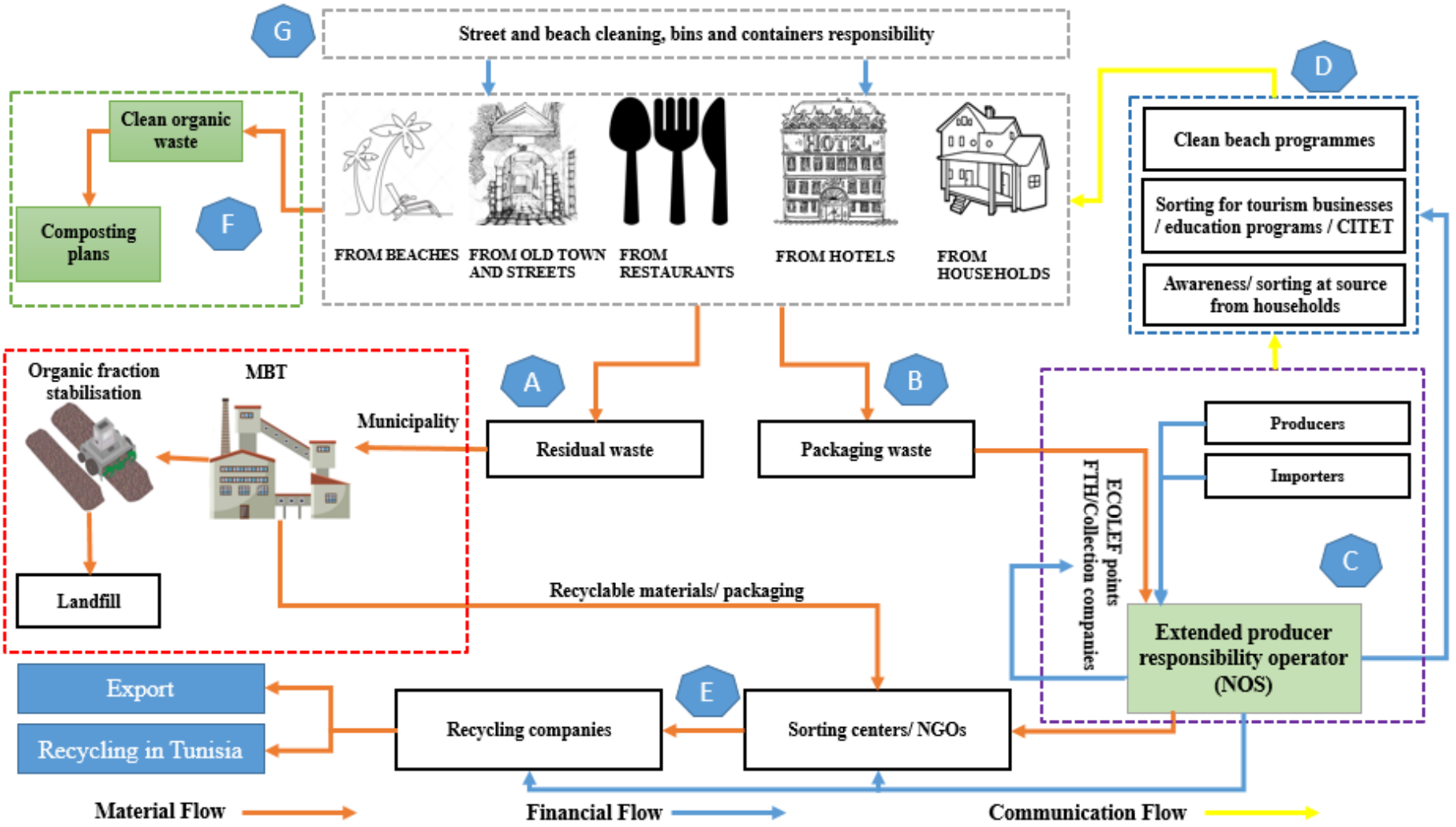

Figure 6-1. *Proposed general possible model for SWM in tourism areas*

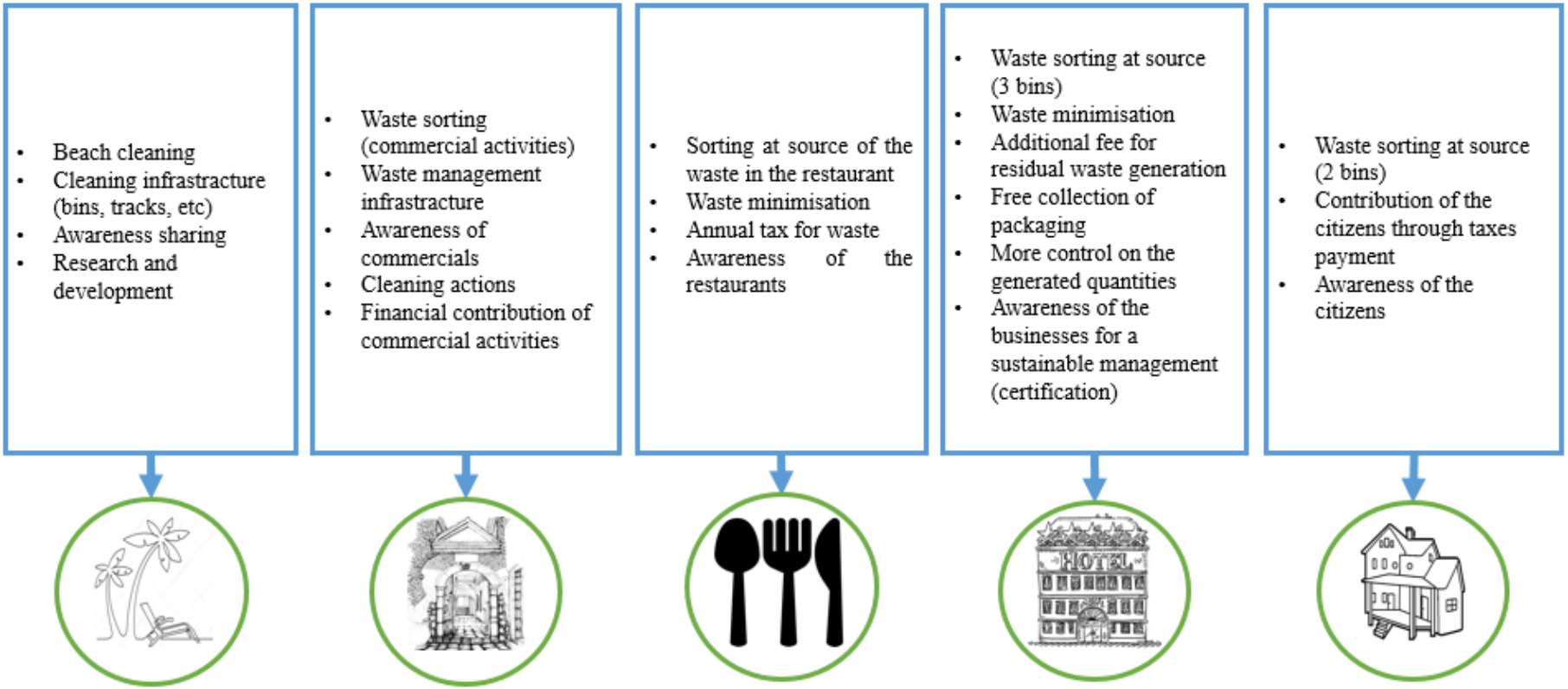

Figure 6-2. *Actions required in different waste generation establishments and areas in tourism*

6.2. PROPOSED SCENARIO FOR SWM IN HAMMAMET CITY

The SWM concept in tourism destinations requires concrete steps to be implemented correctly to ensure its efficiency and sustainability. To do that, an example of the municipality of Hammamet was studied, and possible scenarios aimed at implementing the solution were developed based on the collected facts, figures and data from the municipality and from national authorities.

First of all, and in order to organise the activities and decisions and to ensure the participation of all actors, a working group 'waste and tourism' should be created within the tourism municipality with the support of the municipal council. The group should be composed of representatives from the FTH, civil society and NGOs, staff of the municipality, hotels and local citizens, as well as members of the central government. Private companies for collecting and recycling could also be involved. The working group should organise several discussions and workshops to discuss a suitable organisation structure for all actors and to clarify their organisational and financial roles. The group should elaborate a continued evaluation, control and monitoring of realised actions, based on fixed objectives and performance indicators. Figure 6-3 presents the possible outputs and roles of different actors in Hammamet.

The implementation of these actions should be supported by several awareness actions and sorting at source programmes, which should involve active local NGOs in Hammamet, taking into consideration all performed experiences and practices.

The responsibilities should be assigned, defined by the law, and fixed by the municipality based on the extended discussions. Laws and guidance should refer to the national authorities that defines the principle axes of the strategy, and could include:

- A municipal law to stipulate the separate collection of commercial municipal waste at source (hotels, restaurants, shops, etc.). All recyclable materials have to be collected separately, such as paper and cardboard, glass, plastic, metal and lightweight packaging;
- Guidance fixing the time of waste disposal from households and from tourism establishments;
- A local law (based on a national law) that prohibits the landfilling of green waste and to create at least one composting plant in the municipality;
- A new municipal law fixing waste disposal taxes for restaurants and calibrating the current financial system for hotels.

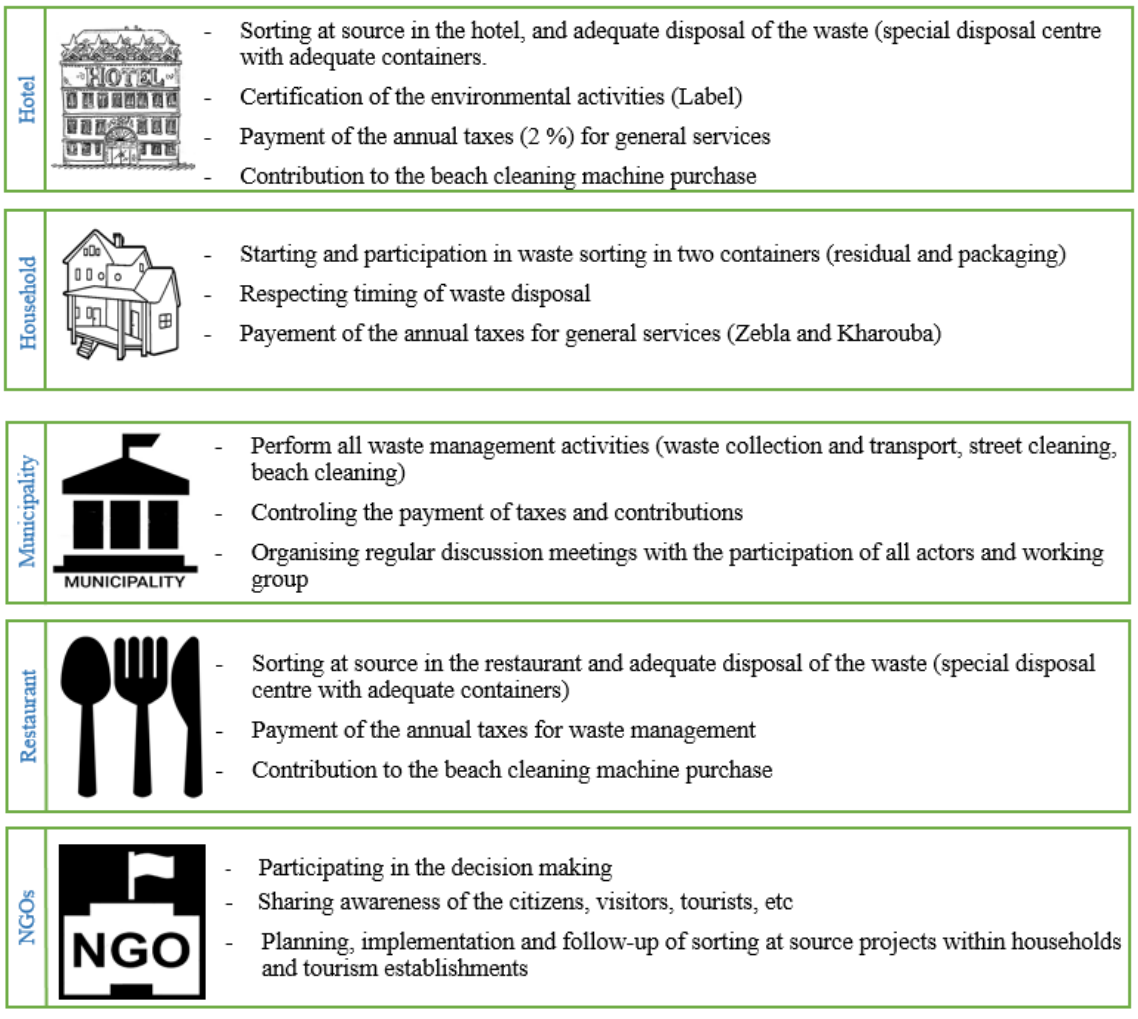

Figure 6-3. *Possible roles of the main actors*

At the moment, a national law for hotel's taxes exists (2% of the turnover, divided into 1% for municipalities and 1% for the national tourism protection fund). Taxes required from the citizens are also fixed, but the recovery rate remains very low. In addition, the municipality of Hammamet benefit from the found of tourism, managed principally by MLAE and Ministry of Tourism. Figure 6-4 represents the incomes (green) and costs (orange) of SWM activities.

Since the need of more financial resources to manage the large amounts of waste, the municipality could extend their revenues (blue). This could be through the application of a waste tax for restaurants (considered also as a big generator of waste), and/or a tax on tourists as consumers, in addition to being involved in the extended producer responsibility concept (which could be an important source of revenues to support SWM activities in the destination).

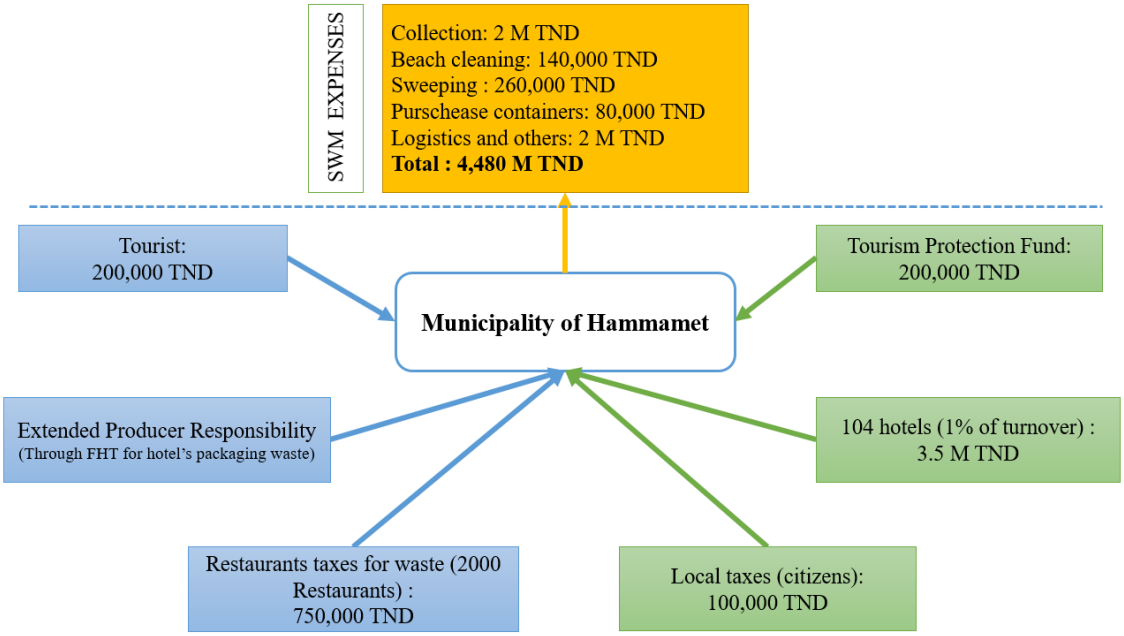

Figure 6-4. *Current expenses and identified possible revenues for municipal SWM in Hammamet*

In Hammamet, hotels represent an important waste generator who contribute more than 35% of the total waste during the year. The municipality ensures the waste collection operation to transfer stations and to the landfill 'Beni Wael' in order to be landfilled and treated by private operators. Indeed, the composition of the solid waste generated from hotels in Hammamet (according to Table 4-2) are summarised in Table 6-1:

Table 6-1. *Summary of the detailed sorting analyses performed in Hammamet.*

Waste fraction	**Percentage (%)**
Organic fraction	55% (52.5% vegetables waste, fruits)
Paper & cardboard	17%
Glass	2%
Plastic	14%
Aluminium	1%
Others	11%

The main action is to ensure the waste sorting at source in hotels in Hammamet to reduce the waste management costs, to avoid landfilling problems and to create new job opportunities through the creation of collection, sorting and recycling businesses.

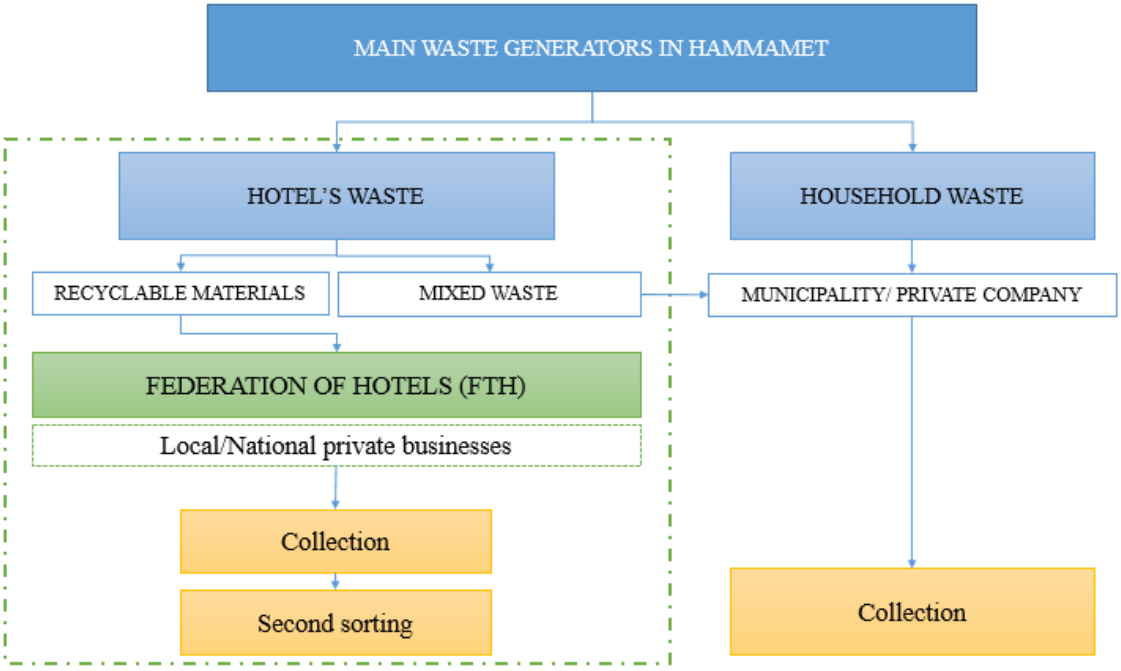

Figure 6-5. *Suggested collection system for waste generated from hotels*

For the case of Hammamet, it is recommended that waste sorting and collection from hotels would be organised by the FTH, through its regional agency, in collaboration with the 'waste and tourism' working group created within the municipality. It should also have a hand in the development of the waste management within the tourism establishments. A special programme in partnership with CITET would be developed in order to support hotels technically, through the implementation of eco-labels. Indeed, this certification could be a good motivation to improve the waste management system within the establishment.

For instance, special requirements for storage at the point of origin in the hotel must be met by the municipality. The containers must be properly closed and inaccessible to animals. The emptying frequency must be adapted to the weather as well as the generation of unpleasant odours and dangerous fermentation processes. The refrigerated storage of residual and organic waste is obligatory and the timing and position of the container should be respected during the collection operation. The objective is to reduce the time of collection, reduce the effort of workers and, consequently, reduce costs.

To ensure a better organisation and management of waste in hotels, these scenarios would be recommended (Figure 6-6).

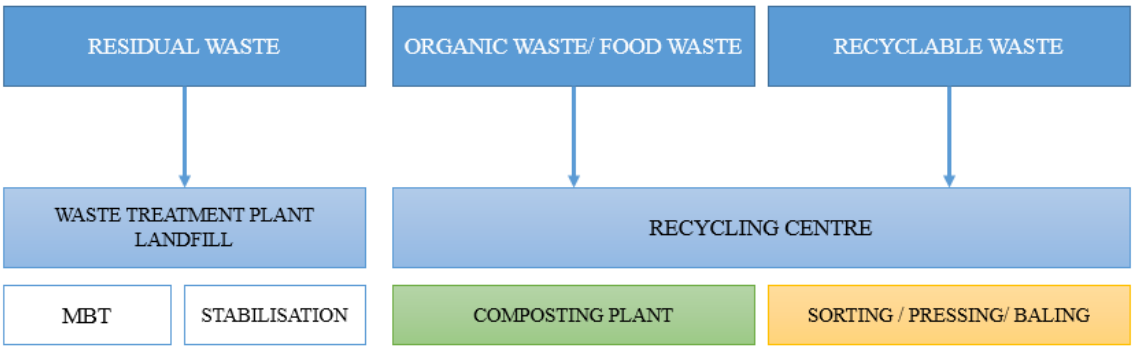

Figure 6-6. *Recommended scenario for SWM in hotels in Hammamet*

With the aim of reducing the amount of waste generated, reducing the collection and treatment costs and improving the recycling rate, hotels should take responsibility for the waste sorting at source. On one hand, they could be excluded from fees payment for the management of the collected recyclable materials and they could also benefit from the compost produced from organic and green waste. On the other hand, the generation of residual waste could be reduced considerably as hotels are obligated to sort the materials correctly to reduce the amount of residual waste generated, and thus reduce collection costs. In the existing concept, the collection of the residual waste without paying fees would be less motivating to sorting at source correctly in hotels.

Regarding the packaging waste, the existent recyclable material represents, according to the results of the sorting analyses from hotels (see Table 4-2), from 30% to 33% of the total waste. It is recommended that FTH create a company to take the responsibility for collecting the recyclable materials and to sorting them again with the aim of recycling. The mission could be also delegated to existent competent enterprise. ECO-Lef points in Hammamet could be exploited for this purpose. This flow should be managed in concertation with the EPR system operator, which is responsible of setting the objectives and paying the FTH for these activities.

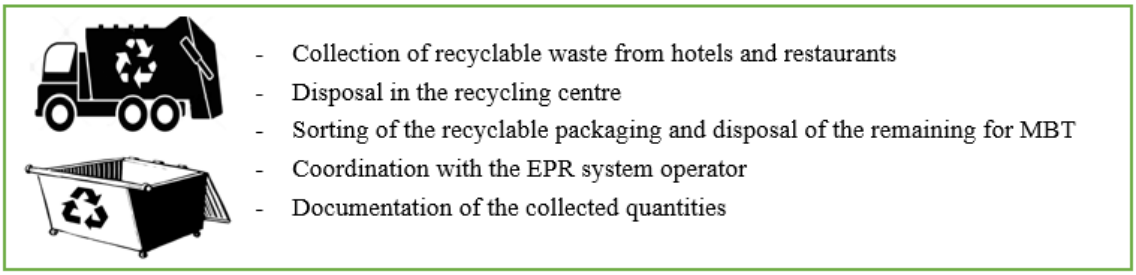

Figure 6-7. *Possible collection and sorting actions*

Concerning the organic and kitchen waste, hotels should do the sorting correctly to ensure a clean product for composting. According to the sorting analyses realised for hotels' waste in Hammamet (Table 4-2), most of the organic waste fraction (52.5% from 55%) was represented by vegetable food (fruits, vegetables), which could be an asset to produce good compost. The composting operation could also be performed if enough space in the recycling centre exists. In addition, the government should support the production of

compost and encourage the investment and the marketing of the product, which is due to its high price compared with chemical fertilisers.

Based on the municipalities' information, and considering the sorting analyses performed on waste generated from hotels, the benefits of the possible scenario of waste sorting at sources in hotels in Hammamet were calculated in Table 6-2. Taking into consideration that the existent infrastructure is not ready to recycle all types of plastic in Tunisia, the scenario of 30% landfilling and 70% valorisation has been chosen.

Table 6-2. *Estimation of the cost saving following the SWM scenario for the current practices and in case of MBT treatment.*

Item	Practice	Costs per ton (TND)	Quantities collected from hotels* (Tons)	Total costs (TND)	MBT
Current costs	100% landfilling	70	13,480	943,600	2,224,200
Suggested concept	30% landfilling 70% valorisation	70	4,044	283,080	667,260

*Year: 2017

Regarding the collection and treatment of waste generated from hotels, and considering that these operation costs around 70 TND per ton in Hammamet (since it is done by the private sector), and that 13,480 tons of waste are generated during the year by hotels alone, the total costs per year could reach 943,600 TND. The costs could be more expensive and can reach 2,224,200 TND, taking into consideration the orientation of the government's aim for the valorisation and the stabilisation of waste through an MBT process (100 TND treatment costs with 65 TND collection costs). In case of sorting at source in hotels in Hammamet, the costs could reach 283,080 TND for the current SWM concept, and 667,260 TND in case of MBT treatment.

This scenario would be feasible only if:

- There is good organisation and a share of responsibilities between all stakeholders;
- Development of adequate laws/orders by the municipality to support the concept;
- The sorting at source is done within the hotels;
- There is capacity building of the hotels regarding waste sorting at source operations;
- There is a development of composting plants within the municipality to accept the generated green and kitchen waste;
- The private companies should be in charge of all the sorting processes of the recyclable waste after collection from hotels.

7. CONCLUSIONS

In Tunisia, several problems related to SWM still exist for reasons as diverse as the economic activities in the country (industry, tourism, commerce, agriculture and services), the accelerated process of urbanisation, the uncontrolled construction of urban and rural areas, the degradation of waste management infrastructure in residential areas and, undoubtedly, the intensive evolution of consumption patterns of the population at the national level.

The situation has become trickier because of changes in the behaviour of the waste generators, especially in the post-revolutionary period, which has been characterised particularly by ignorance, incivility and indiscipline, the trouble of communicating with stakeholders, the insufficient financial capacity of the local authorities, as well as a notable absence of monitoring tools. These aspects are considered to be main challenges to managing the amounts of waste generated, and to handling the daily technical issues related to the collection, transportation, disposal, treatment and recovery. These activities are, at the moment, considered ineffective and not working correctly enough to ensure a sustainable and integrated SWM concept in Tunisia.

Currently, recyclable materials from households and industries such as plastic, glass, paper, metals and textiles are still not separately collected in the country; what is more, organic waste is mixed with all other types of waste by the generators. Only about 5% of materials are recovered as recyclable materials and these are mainly collected and sorted by "Barbechas", picking it up from the collection containers on the street, or from landfills and dumpsites to earn a living. The rest of the non-accessible and uncollected recyclable materials are either not collected, dumped or landfilled, and could be found via several climatic and other conditions on the roads, beaches and the marine environment.

Solid waste in tourism destination is related to waste generated from households, hotels and restaurants, old towns, in beaches, street cleaning, etc. Considering that Tunisia has an important and growing tourism activity, and recognising the seriousness of the deterioration of living conditions of local citizens, tourists and visitors, as well as the quality of the destination and the tourism industry in the country, the objective is to improve this situation by establishing a sustainable and innovative SWM concept for tourism in Tunisia. Developing a sustainable SWM model should take into consideration all these waste generators in addition to the whole SWM process from the collection to the treatment, valorisation or recycling.

The results of our research shows that the tourism sector in Tunisia represents a potential generator of solid waste, especially during the summer period. Tourists and local guests generate large amounts of waste during their stays in hotels compared to waste generated from households. The generated waste is principally organic, having as the main source independent restaurants, along with hotels' restaurants and kitchens. These establishments offer principally buffet services, which generates more organic waste. Other types of packaging are generated from these establishments by the hotels' activities as well as guest' consumption. The increased waste generation is also due to the increase of local people who live abroad and return during the summer for holidays.

The Tunisian government announced after the elections of May 2018, the official change to a decentralised decision making, including the SWM sector, which aims to transfer responsibility for solid waste operations to local authorities. However, the lack of data and information represents one of the big challenges facing the authorities and decision makers. Therefore, an urgent need exists to develop special key indicators to be analysed in order to support decision makers to define adequate laws and actions.

In the framework of this PhD, and in order to support the diagnostic of the current SWM in tourism destinations in Tunisia, several technical, financial, institutional, legal and social key indicators were developed as a tool to collect data and to diagnose the current SWM situation in tourism in Tunisia. The objective is to support decision making in the shift toward sustainable solutions that are adapted to the Tunisian context.

The recommended options developed in this work should not be considered as final and conclusive solutions to the problem of SWM in tourism destinations for the case of Tunisia. Indeed, other actions should be taken to improve the designed concept, to optimise it during the implementation phase and to insure its sustainability.

Based on the diagnostic of the situation at national level and in some tourism municipalities in Tunisia such as Hammamet and Gammarth, some suitable organisational solutions were developed. The proposed scenarios highlight that the responsibilities of the different partners should be clarified and the process should involve all stakeholders including also the FTH, tourism establishments, private companies, NGOs, etc. Indeed, considered as one of the basis of the decentralisation process, the collaboration of the different stakeholders contribute to optimising the decision making and reducing the financial and technical pressure on the local authorities. The extensive discussions with local and national authorities confirms their readiness to establish a new organisational concept, including all actors of the sector, to ensure an integrated SWM concept for tourism and to guarantee a clean destination during the year.

Second, in order to ensure clean tourism destinations (beaches, marine environment, etc) free from packaging, to increase the recycling rate and to improve the design of the products at source, we recommend an EPR concept to optimise the existing ECO-Lef system. At the moment, the latter collected only 3,400 tons in 2018, compared to 15,800 tons in 2010. A series of discussions, workshops and meetings with different project actors agreed on creating a non-for-profit organisation called the ‘New System Operator’ (NOS) to be in charge of operating the system. This organisation is to be financed by the producers who put packed goods on to the Tunisian market. The role of ANGED within the system will be controlling and fixing the legal framework as well as the national objectives. The EPR system aims to increase the collected recyclable materials, to reach the target and to ensure the financial sustainability through the extension of the responsibility of the producer, which will support the system operator financially; thus, it will support the effort to improve the design of the products put into the market. In addition, EPR also indirectly supports the creation of new businesses and new job opportunities.

Furthermore, a small-scale kitchen bio-waste and green waste composting project conducted in La Marsa tourism municipality proved that a good quality final product can be achieved, which can be used as compost for agricultural, private and municipal usage.

As showed in the sorting analyses of the cases of Hammamet and Gammarth, organic waste represents a big challenge. On one hand, this fraction is particularly composed of kitchen waste generated from tourism establishments resulting from the preparation, rest of food and non-consumed food. On the other hand, green waste is generated from green spaces and yard clippings (leaves, grass clippings, vegetable or other garden debris, shrubbery, or brush and tree trimmings). The final product quality findings showed that concentrations of all seven heavy metals (Pb, Zn, Cu, Cd, Cr, Hg and Ni) were within the set limits and were much lower than the German and the Tunisian standards. The respiration activity test (AT4) showed that the compost production process was performed successfully and under ideal conditions.

The main objectives of the proposed solutions for SWM in tourism areas in Tunisia are:

- Improvement of the efficiency of the waste management activities (waste collection, recycling, cleaning, etc.) in tourism destinations in Tunisia, mainly from commercial and tourism establishments, households, streets, beaches, old towns, etc.;
- Improvement of the recycling rate and reduction of littering in tourism destinations and increase the satisfaction of the tourists and visitors;
- Reducing the SWM costs and ensuring more incomes for municipalities, public and private sector working active in the sector;
- Creation of new job opportunities and supporting the economic sector (enforcement of the tourism sector, support waste management companies, etc.);
- Minimising the waste to be landfilled, thus reducing CO_2 emissions.

However, the implementation of suitable alternatives for SWM in the tourism sector in Tunisia should be accompanied by other actions, for instance, establishing a sustainable market for the output material, development of the recycling infrastructure for more recyclable fractions, the reduction and minimisation of waste through the sorting at source, as well as the continued raising awareness and education of the different waste producers. In addition, the improvement of the research and the involvement of NGOs in the SWM sector could reinforce the sustainability of the concept.

8. RECOMMENDATIONS

Developing an integrated and a sustainable SWM concept in tourism in Tunisia, considering the total activities (waste collection, transfer and transport, treatment and disposal, street and beach cleaning), supported by a clear legal, organisational and institutional framework, must be adopted to ensure clean tourism areas during the year, and to manage the large amounts of waste generated during the summer period suitably and sustainability. Furthermore, financial and human resources' empowerment represents an important asset toward achieving the goals.

A sustainable institutional and organisational plan for SWM in tourism areas should clarify the responsibilities of different actors. Other actions should be taken into consideration, for instance, the monitoring and evaluation of the operational services and the involvement of the private sector by ensuring fair competition between private companies' service providers and between the public and private sectors.

The current decentralisation process, and the transfer of decisions to local government in Tunisia, represents a good asset that should be reinforced to improve the SWM sector in the country, and particularly in tourism zones.

The concept for SWM should be based on a participatory approach that would engage local citizens and civil society in the decision-making process; this would reduce opposition towards SWM strategies and actions, delegate treatment that incentivises municipal cooperation and permits the installation of methodologies and technologies that reflect the constraints and public attitudes of each geographical territory. In addition, it would deconcentrate disposal, which would limit the number of landfills constructed and facilitate the monitoring. It is also to be noted that the sustainability of a decentralised framework is dependent on the level of fiscal and political autonomy that local authorities own, the degree that subnational governments collaborate with each other and with public, private and non-governmental stakeholders (NGOs for example), and the degree at which policies and regulations are implemented.

Further, the success of a SWM decentralisation process in Tunisia remains associated to the finalisation of the legal and administrative operation, and the transfer of the decision making in the SWM sector to local authorities. This needs a coherent national strategy and a legislative framework with clear monitoring mechanisms. In addition, decentralised structures require rerouting revenue-generating processes from central government towards local authorities, which would confirm the fiscal and political sovereignty of regional administrations and reduce the involvement of the national government. Furthermore, the performance of decentralised strategies should be continuously monitored by the national government and local citizens to ensure that local administrators are held accountable for any mismanagements.

However, several recommendations could be suggested to improve the SWM in tourism destinations in Tunisia and to satisfy tourists and visitors:

- The efficiency of SWM frameworks can be improved through the establishment of different activities (training and awareness programmes that advance the technical and environmental competence of municipal workers).
- Education and capacity building: In order to solve the problem of lack of professional expertise, know-how and experience within local and national authorities as well as private tourism and waste management companies, specific training programmes could be arranged for decision makers and other responsible parties; this could support the exchange of good practices with other countries and international institutions.
- Ensuring public education, sharing awareness with local citizens and communicating what is required from all stakeholders. This will confirm their engagement in the process. Tourists and guests are also concerned by the education programmes as they are considered to be main producers of waste in tourism, e.g., in hotels, on the beaches and roads, etc.
- Waste sorting at source: The establishment of a new EPR system will open the doors to launch new experiences related to waste separation at source in households as well as tourism industries, in order to improve material recovery and collection, which should be highly considered in Tunisia. Second, the waste segregation and separation at source could support the efforts to reduce the waste generation and reduce SWM costs (collection, transport, landfilling, etc.) and valorisation through the minimisation of the investment costs (such as MBT plants). It would be an asset to increase the available clean material for collection and recycling, which would create new businesses and job opportunities. It is worth mentioning that the planned sorting at source experience should take into account previous good and unsuccessful experiences.
- Green waste composting has been identified as a crucial waste management approach for tourism destinations in Tunisia. To do that, a special system for green waste collection and transporting should be developed. Indeed, a public-private partnership concept is recommended to establish this process. Furthermore, the regulation should be clear in this direction, through the prohibition of the green waste being landfilling by ANGED operators. In addition, the responsible agency should create incentives to encourage such a project through the support of the compost market, which currently represents a considerable barrier.
- Food waste sorting at source: Tourism establishments should collect the kitchen organic waste separately to guarantee clean raw material for composting. This process reduces the quantities of waste collected and landfilled, thus reducing CO_2 emissions and collection costs. Moreover, donating edible surplus hotel food can help reduce the amount of edible food sent to compost, landfill or other end-of-life solutions, thus reducing CO_2 emissions in the environment. It also helps the local community and preserves the resources that went into making the food. This procedure should be coordinated with the composting plants.
- Financially, and in order to ensure clean and sustainable tourism destinations in Tunisia, many actions will require a sufficient budget. Therefore, the budget of the

SWM activities in tourism destinations should be enhanced. First, as an organisational step, the involvement of all the waste management sector actors in tourism municipalities could solve several problems by sharing the financial costs between different partners, which could reduce the financial pressure on the municipality. In addition, commercial and tourism enterprises should contribute to the SWM system, through the payment of annual taxes, in receipt of waste collection and treatment services. Moreover, the community should pay the fee for waste disposal and for services provided by the municipality. This will support the financial resources to guarantee the efficiency of SWM services. In addition, a tax for tourist stay per night could be applied. Further, the polluter-pays principle should be introduced with the development of an EPR system, which will be financed, principally, by all the producers and importer of goods.

- Integration of waste pickers: Establishing an integrated and a sustainable SWM concept in tourism in Tunisia should include waste pickers, particularly for the material recovery operation. Their integration into the concept should be investigated and aim at improving waste recovery and working conditions for waste pickers.
- Beach cleaning should be considered as an important service for the municipality, to satisfy the visitors and tourists, particularly during the summer period. Mechanical and manual cleaning should be planned according to several parameters. It is also recommended to create a particular team to focus on these activities.
- The government should encourage partnerships and the development of better SWM concepts for tourism destination based on waste reduction, reuse, recycling and composting. In addition, the government should reinforce businesses and communities through the development of pilot projects, funding, training sessions, technical assistance, information exchanges, follow-up support and monitoring. For instance, the municipality can encourage private small composting projects through elaborating contract to get the product during 3 to 5 years to be used for municipal or private activities. Furthermore, based on the development of regulations, their enforcement and creating economic incentives, the government should encourage better waste management practices and help create markets and increase the value of different waste materials to ensure its collection and recycling. Educational activities such as the organisation of conferences, seminars and workshops, publication of training manuals, case studies and best practices, and the provision of technical and financial assistance, should also be conducted.
- The Tunisian government is requested to work on both ‘bottom up’ and ‘top down’ approaches. A ‘bottom up’ approach, which is urgent, aims at the rehabilitation of the remaining open dumpsites that still exist in three tourism areas; a ‘top down’ approach is based on minimising waste at source, waste valorisation and stabilisation before landfilling, which need more time and efforts to be done.
- A national strategy for SWM should be built to integrate sustainable and participatory management of household and solid waste and to overcome the challenges and problems arising from the diagnosis of the previous policy. The elaboration of the strategy should include all national experts and stakeholders.

REFERENCES

1. Giurea, R., Precazzini, I., Ragazzi, M., Achim, M.I., Cioca, L.I., Conti, F., Torretta, V., Rada, E.C., 2018. Good practices for a sustainable municipal solid waste management. Resources, Vol.7, pp. 51. https://doi.org/10.3390/resources7030051.
2. Edmundo, M., Rodrigo, N., 2015. Waste management in touristic regions. Waste Management and Research, Vol.33, pp. 593–594. DOI: 10.1177/0734242X15594982.
3. Makule D.E., 2000. Pollution of water sources due to poor waste management--the case of Dar-es-Salaam, Schriftenreihe des Vereins für Wasser-, Boden- und Lufthygiene, Vol.105, pp.117-21.
4. Sastre, S., 2015. Zero Waste Europe, Air pollution from waste disposal: Not for public breath, DOI: 10.13140/RG.2.1.5074.0560.
5. Pervez, A.K.A., 2013. Impact of solid waste on health and the environment, International journal of sustainable development and green economics (IJSDGE), ISSN No.: 2315-4721, V-2, I-1, 2.
6. Lisa, S., Lorenzo, G., Derek, P., 2003. The human health impact of waste management practices: A review of the literature and an evaluation of the evidence. Management of Environmental Quality An International Journal, Vol.14, No.2, pp.191-213, DOI: 10.1108/14777830310470422.
7. Magrinho, A., Didelet, F., Semiao, V., 2006. Municipal solid waste disposal in Portugal. Waste Management. Vol.26, No.12, pp.1477–1489.
8. Rotich, K., Zhao, Y., Dong, J., 2006. Municipal solid waste management challenges in developing countries – Kenyan case study. Waste Management. Vol.26, pp. 92–100. https://doi.org/10.1016/j.wasman.2005.03.007.
9. Manga, V., Forton, O., Read, A., 2008. Waste management in Cameroon: a new policy perspective? Resources, Conservation and Recycling. Vol.52, pp.592–600. https://doi.org/10.1016/j.resconrec.2007.07.003.
10. Shekdar, A., 2009. Sustainable solid waste management: an integrated approach for Asian countries. Waste Management. Vol.29, pp.1438–1448.
11. Mathieson, A., Wall, G., 1982. Tourism: economic, physical and social impacts. Longman.
12. Gidarakos, E., Havas, G., Ntzamilis, P., 2006. Municipal solid waste composition determination supporting the integrated solid waste management system in the island of Crete. Waste Management. Vol.26, pp.668–679. https://doi.org/10.1016/j.wasman.2005.07.018.

13. Radwan, H., Jones, E., Minoli, D., 2010. Managing solid waste in small hotels. Journal of Sustainable Tourism, Vol.18, No.2, pp.175–190. https://doi.org/10.1080/09669580903373946.

14. Gutierrez, E., Lamoureux, K., Matus, S., Sebunya, K., 2005. Conservation international, linking communities, tourism & conservation: a tourism assessment process; Conservation International, George Washington University: Washington, DC, USA, ISBN 1-8811 73-43-7.

15. IFC Environmental, 2007. Health, and Safety Guidelines for Tourism and Hospitality Development IFC, Washington D.C. Available online: https://www.ifc.org/wps/wcm/connect/topics_ext_content/ifc_external_corporate_site/sustainability-at-ifc/policies-standards/ehs-guidelines/ehsguidelines (accessed on 28 September 2019).

16. Liu, T.-K., Wang, M.-W., Chen, P., 2013. Influence of waste management policy on the characteristics of beach litter in Kaohsiung, Taiwan. Marine Pollution Bulletin, Vol. 72, pp.99–106. https://doi.org/10.1016/j.marpolbul.2013.04.015.

17. Switchmed.eu, Tunisia Ecotourism: follow a sustainable circular economy tourism model that is a far cry from mass coastal tourism, 2017. Available online: https://www.switchmed.eu/en/country-hubs/tunisia/actions/tunisia-ecotourism (accessed on 30 October 2018).

18. Kapitalis, Djerba: Houmet- Souk, ville dévastée par les déchets, 2018. Available online: http://kapitalis.com/tunisie/2018/06/24/djerba-houmt-souk-ville-devastee-par-les-dechets/ (accessed on 30 September 2018).

19. Günay, K., 2000. Solid waste management in developing countries — A case study of Turkey, Sustainable solid waste management in the Southern Black Sea Region, pp 47-68, https://doi.org/10.1007/978-94-010-0940-9_3.

20. Nassour, A., Hemidat, S., Chaabane, W., Eickhoff, I., Nelles. N. 2018. Aktuelle Entwicklungen in der Abfallwirtschaft im arabischen Raum, Mull und Abfall Journal, https://www.muellundabfall.de/MA.04.2018.160.

21. Medina, 2002. Globalisation, development and municipal solid waste management in Third World Cities. Tijuana, Mexico: El Colegio de la Frontera Norte, pp.1-23.

22. Zerboc, O., 2003. Urban solid waste management: waste reduction in developing nations' school of forest resources and environment science, Michigan Technological University, Working paper.

23. Naas, A., 2015. Actual situation and approach for municipal solid waste treatment in the arab region, Department of Waste Management and Material Flow, Rostock University.

24. Nassour, A., Al-Ahmad, M., Elnaas, A., Nelles, M., 2011. Practice of waste management in the Arab region. Contribution in: kule-weidemeier, M., water-to-

resources 2011-4. International conference MBT and sorting systems, conference proceedings, 24-26 May 2011, pp. 81-91, ISBN 978-3-86955-747-2 (05/2011).

25. Abaza, H., Saab, N., Zeitoon, B., 2011. Arab environment.4 green economy; sustainable transition in a changing Arab World. Report of the Arab Forum for Environment and Development (AFED), Lebanon.
26. Jafari, J., Noel, S., 2014. Muslim world and its tourisms. Annals of tourism research, Vol.44, pp.1–19.
27. UNWTO World Tourism Organization, 2018, Tourism Highlights, 2018 Edition, UNWTO, Madrid, DOI: https://doi.org/10.18111/9789284419876.
28. Azomining, 2012. Tunisia: mining, minerals and fuel resources, https://www.azomining.com/Article.aspx?ArticleID=197 (accessed on 28.06.2019).
29. Loschi, C., 2019. Local mobilisations and the formation of environmental networks in a democratizing Tunisia. Social Movement Studies, Vol.18, No. 1, pp.93-112, DOI: 10.1080/14742837.2018.1540974.
30. Ministry of Local Affaires and Environment, Tunisia, 2017.
31. WWF, 2019. La Tunisie: gros pollueur plastique en méditerranée. Available online: https://www.realites.com.tn/2019/06/la-tunisie-gros-pollueur-plastique-en-mediterranee/?fbclid=IwAR35QQkMtw1rT60ebigAaIiRtjuhpsaQnrKZEu3spt2lIdL4yTqFFzGBy0g (accessed on 10 June 2019).
32. Zurbrügg, C., 2003. Waste management in developing countries, Eawag and Sandec. Available online: https://www.eawag.ch/fileadmin/Domain1/Abteilungen/sandec/publikationen/SWM/General_Overview/Zurbruegg_2002_SWM_DC.pdf (accessed on 28.06.2019).
33. Al-Jarallah, R., Aleisa, E., 2014. A baseline study characterizing the municipal solid waste in the State of Kuwait. Waste Management. Vol.34, No.5, pp.952-60. doi: 10.1016/j.wasman.2014.02.015.
34. Salah Abu-Salah, A.A.-S., Ammar Abu-Draisc, Ammar Abu-Draisc. 2013. MSW Composition Analysis – Case Study: Amman City, Jordan. D-waste.
35. National Waste Management Agency (ANGED), Tunisia, 2018.
36. World Tourism Organization, 2017. UNWTO Tourism Highlights, 2017 Edition, DOI: https://www.e-unwto.org/doi/pdf/10.18111/9789284419807.
37. World Tourism Organization, 2018. UNWTO Tourism Highlights, 2018 Edition, Madrid, DOI: https://doi.org/10.18111/9789284419876.
38. Basak, T., 2007. The impact of the European Landfill Directive on waste management strategy and current legislation in Turkey's specially protected areas, Resources Conservation and Recycling, Vol.52, pp. 119-135, DOI: 10.1016/j.resconrec.2007.03.003.

39. Jiang, J., Lou, Z., Ng, S., Luobu, C., Ji, D., 2009. The current municipal solid waste management situation in Tibet. Waste Management. Vol.29. pp.1186-91. doi: 10.1016/j.wasman.2008.06.044.

40. Cierjacksa, A., Behrb, F., Kowarika, I., 2012. Operational performance indicators for litter management at festivals in semi-natural landscapes. Ecological Indicators, Vol.13, pp. 328–337.

41. Kharbanda, O.P., Stallworthy, E.A., 1990. Waste management: towards a sustainable society. Greenwood Press.

42. Frederico, N., 2003. A new approach to sustainable tourism development: moving beyond environmental protection, Wiley Online Library, Vol.27, N.3, pp. 212-222, https://doi.org/10.1111/1477-8947.00056.

43. Gruber, I., Obersteiner, G., Ramusch, R., 2016. Urban strategies for waste management in tourist cities, European Union H2020, Available online: http://www.urban-waste.eu/wp-content/uploads/2017/09/Status-quo-baseline-assessment-report.pdf (accessed on 28 November 2018).

44. Christina, B.M., Costa, A.M.F., 2016. Municipal services on tourist beaches: costs and benefits of solid waste collection. Journal of Coastal Research, Vol.22, N.5: pp. 1070 – 1075.

45. Edmundo, M., Rodrigo, N., 2015. Waste management in touristic regions. Waste Management and Research, Vol.33, pp.593–594.

46. Zero waste Europe, 2017.

47. Mwanzaa, B.G., Mbohwaa, C., Telukdariea, A., 2018. Strategies for the recovery and recycling of Plastic Solid Waste (PSW): a focus on plastic manufacturing companies. procedia manufacturing, Vol.21, pp.686–693.

48. Rodrigues,S., Martinho, G., Pires, A. 2016. Waste collection systems. Part A: a taxonomy, Journal of Cleaner Production, Vol.113, pp.374-387, https://doi.org/10.1016/j.jclepro.2015.09.143.

49. Amponsah, S.K., Salhi, S., 2014. The investigation of a class of capacitated arc routing problems: the collection of garbage in developing countries. Waste Management, Vol.24, No.7. pp.711-21. DOI: 10.1016/j.wasman.2004.01.008.

50. Carchesio, M., Tatàno, F., Goffi, M., Radi, M., 2015. Environmental and social sustainability of the proximity waste collection system: a case-study evaluation at an Italian local scale. Sustainability, Vol.7, pp.7492-7511.

51. Swimming beach cleaning policy, overstrand municipality, Approved by Council, 3 December 2014, available on: https://www.overstrand.gov.za/en/documents/policies/1734-swimming-beach-cleaning-policy/file (accessed on 20 June 2019).

52. Construction week online, Dubai Municipality automates beach cleaning fleet, 2016. Available online: https://www.constructionweekonline.com/article-41398-dubai-municipality-automates-beach-cleaning-fleet (accessed on 22.07.2019).

53. Limassol Municipality, 2016. Municipal beach cleaning in Limassol (Cyprus), Marine Litter in European Seas - Social Awareness and Co-Responsibility. Available on: www.marlisco.eu/Municipal_beach_cleaning_in_Limassol.en.html?articles=municipal-beach-cleaning-in-limassol-cyprus (accessed on 15 June 2019).

54. Segnestam, L., 2002. Indicators of environment and sustainable development; theories and practical experience, paper No. 89; The World Bank: Washington, DC, USA.

55. Bahia, S.R., 1995. Sustainability indicators for a waste management approach. Master's Thesis, University of Leeds, Leeds, UK.

56. Rosenstrom, U., 2002.The potential for the use of sustainable development indicators in policy making in Finland. Futura, Vol. 2, pp.19–25.

57. Ceron, J., Dubois, G., 2003. Tourism and sustainable development indicators: The gap between theoretical demands and practical achievements. Current Issues in Tourism, Vol. 6, No. 1, pp. 54–75.

58. Ristić, G., 2005. Basic Indicators of Integrated Solid Waste Management, Faculty of Occupational Safety Niš. Facta Universitatis, Series: Work. Living Environ. Protection, Vol. 2, pp.383–392.

59. Crompton, R., 2012. United Nations Environment Programme, Annual Report 2011, ISBN: 978-92-807-3244-3, Available on: http://wedocs.unep.org/bitstream/handle/20.500.11822/8053/-UNEP%202011%20Annual%20Report-20121086.pdf?sequence=5&isAllowed=y (accessed on 10 June 2019).

60. Ofner, H., 2011. Abfallaufkommen und Abfallsammlung in historischen Städten mit Tourismus, Universität für Bodenkultur, Available online: https://abstracts.boku.ac.at/download.php?dataset_id=8829&property_id=107

61. Khan, D., Kumar, A., Samadder, S.R., 2016. Impact of socioeconomic status on municipal solid waste generation rate. Waste Management, Vol.49, pp.15-25. doi: 10.1016/j.wasman.2016.01.019.

62. Zein, K., Wazner, M.S., Meylan, G., 2008. Best environmental practices for the hotel industry. sustainable business associates. Available online: http://www.sbaint.ch/spec/sba/download/BGH/SBABGEHOTELLERIEENG2008.pdf (accessed on 02.03.2019).

63. Pham Phu, S.T., Hoang, M.G., Fujiwara, T., 2018. Analyzing solid waste management practices for the hotel industry. Global J. Environmental Sciences Management, Vol.4, No.1, pp.19-30, DOI: 10.22034/gjesm.2018.04.01.003.

64. Winter, J.P., Azimi, S.L., 1996. Less garbage overnight: a waste prevention guide for the lodging industry. Available online: http://infohouse.p2ric.org/ref/03/02129.pdf (accessed 02.03.14.).

65. Evans, T., 2008. The study of environmental awareness and waste minimization approaches for Hotel management in Belize. National Central University, Taiwan.

66. WRAP UK, 2012a. The composition of waste disposed of by the UK hospitality industry. Available online: http://www.wrap.org.uk/content/compositionwaste-disposed-uk-hospitality-industry-1 (accessed on 29.01.19.).

67. WRAP UK, 2012b. Company structure and governance. Available online: http://www.wrap.org.uk/content/governance-1 (Accessed on 02.03.19).

68. Parfitt, J., Eatherley, D., Hawkins, R., Prowse, G., 2013. Waste in the UK hospitality and food service sector (Technical Report No. HFS001-00 6), Waste and Resources Action Programme (WRAP), UK.

69. Zangmo, C., Sharp, A., 2017. Solid waste generation, composition and management in Paro hotel industry. Applied Environmental Research, Vol. 39, No.2, pp.15-27.

70. Nath, A., 2014. Profitability and sustainability from waste management practices in hotels and its impact on environment (Doctor of philosophy), Jaypee Institute of Information Technology.

71. Majid, M.R., 2007. Sustainable solid waste management for island resorts: potential for Perhentian Island, Terengganu. In: Presented at the 1st International Conference on Built Environment in Developing Countries, Pulau Pinang, Malaysia.

72. Mongtoeun, Y., Fujiwara. S.S.T, 2014. A Study of commercial solid waste generation and composition in Phnom, Penh City, Cambodia. Journal of Natural Sciences Research, Vol.4, No.13, Special Issue, https://www.researchgate.net/publication/264084303.

73. Mavropoulos, T., 2015. Zero waste hotels: challenges & opportunities. Available online: http://uest.ntua.gr/tinos2015/proceedings/pdfs/tsakona_mavropoulos.pdf (accessed on 02.03.2019).

74. Lazarevic, D., Buclet, N., Brandt, N., 2010. The influence of the waste hierarchy in shaping European waste management: the case of plastic waste. Regional Development Dialogue, Vol.31, No.2, pp.124-148.

75. Chertow, R.M., 2000. Industrial Symbiosis: Literature and Taxonomy, Annual Review of Energy and the Environment, Vol. 25, pp.313-337, https://doi.org/10.1146/annurev.energy.25.1.313.

76. WRAP., 2015. Household Food Waste in the UK. Available on: http://www.wrap.org.uk/sites/files/wrap/Household_food_waste_in_the_UK_2015_Report.pdf (accessed on 02.04.2019).

77. Buckley, R.C., Araujo, G.F., 1997. Environmental management performances in tourism accommodation. Annals of Tourism Research, Vol.24, No.2, pp.465-469.

78. Pigram, J.J., Wahab, S., 1997. Tourism, development and growth: the challenge of sustainability. Routledge: London.

79. Mawforth, M., Munt, I., 1998. Tourism and sustainability, new tourism in the third world. Routledge: New York.

80. Bohdanowicz, P., 2005b. Environmental awareness and initiatives in the Swedish and Polish hotel industries – survey results. International Journal of Hospitality Management, Vol.25, pp.662-682.

81. Rivera J., 2004. Institutional pressures and voluntary environmental behaviour in developing countries: Evidence from the Costa Rican hotel industry. Society and Natural Resources, Vol.17, pp.779-797.

82. Bohdanowicz, P., 2005a. European hoteliers' environmental attitudes – greening the business. Cornell Hotel and Restaurant Administration Quarterly, Vol.46, No.2, pp.188-204.

83. Irene, H., Perry, S., 1999. The relationship between environmental commitment and managerial perceptions of stakeholder importance. Academy of Management Journal, Vol. 42, No. 1, pp.87-99. URL: http://www.jstor.org/stable/256876.

84. Sanjay, S., Harrie, V., 1998. Proactive corporate environmental strategy and the development of competitively valuable organizational capabilities. Strategic Management Journal. Vol.19, pp.729–753.

85. Branzei, O., Jennings, PD., Vertinsky I., 2002. A knowledge-based view of environmental performance in different cultural contexts: Canada, Japan, and China. Paper presented at the Academy of Management Conference (Organizations and the Natural Environment Division).

86. Brian, A.W., 2005. Tourism and sustainability: development and new tourism in the third world. Annals of Tourism Research, Vol.32, No.2, pp.499-501.

87. Vinod, S., Ercan, S.T., Deborah, K., 2002. Developing countries and tourism Ecolabels. Tourism Management, Vol. 23, No.2, pp.161-174, DOI: 10.1016/S0261-5177(01)00047-4.

88. Paulina, B., 2005. European hoteliers' environmental attitudes: greening the business. cornell hotel and restaurant administration quarterly, Vol.46. pp.188 https://doi.org/10.1177/0010880404273891.

89. Pirani, S.I., Hassan, A.A., 2014. Solid waste management in the hospitality industry: A review. Journal of Environmental Management, Vol.146, pp. 320–336.

90. Green Yatra, Environmental Association. 2014. Available online: https://www.greenyatra.org/ (accessed on 02.04.2019).

91. Altinay, M., Hussain, K., 2005. Sustainable tourism development: a case study of North Cyprus. International Journal of Contemporary Hospitality Management, Vol.17, No.3, pp.272-280, https://doi.org/10.1108/09596110510591963.

92. Greco, G., Cenciarelli, V.G., Allegrini, M., 2018. Tourism's impacts on the costs of municipal solid waste collection: Evidence from Italy. Journal of Cleaner Production, Vol.177, pp.62-68 doi: 10.1016/j.jclepro.2017.12.179.

93. Mendes, P., Ana, C.S., Luis, M.N., Margarida, R.T., 2013. Evaluating municipal solid waste management performance in regions with strong seasonal variability. Ecological Indicators, Vol. 30, pp.170–177, DOI: 10.1016/j.ecolind.2013.02.017.

94. Chaabane, W., Nassour, A., Nelles, M., 2018. Solid waste management key indicator development for hotels: a Tunisian case study analysis. Recycling, Vol.3, pp.56.

95. Styles, D., Schönberger, H., Galvez, M., 2013. Best Environmental Management Practice in the Tourism Sector; European Commission: Brussels, Belgium; Luxembourg City, Luxembourg.

96. Umweltpakt Bayern, Hotel Domicil, Müllvermeidung beginnt beim Einkauf 2002. Available online: https://www.umweltpakt.bayern.de/download/hinweise/Hotel_domicil.pdf (accessed on 02.05.2019).

97. EU-Recycling, 2017. Bergmann Abfall-Pack-Station senkt Entsorgungskosten im Hotelbetrieb. EU-Recycling S. 41.

98. Erbenschwanger, V. u.-G., 2015. eva-abfallentsorgung.de. Available online: http://www.eva-abfallentsorgung.de/preise-und-gebuehren.html (accessed on 02.5.2019).

99. Hamele, H., Eckardt, S., 2006. Umweltleistungen europäischer Tourismusbetriebe. Saarbrücken: ECOTRANS e.V.

100. Appasamy, P.A., Nelliyat, N., 2007. Financing solid waste management: issues and options. Proceedings of the International Conference on Sustainable Solid Waste Management, Chennai, India. pp. 537-542.

101. Diskin, E., 2019. Matador Network, Bali set to impose a tourist tax to keep the island pristine. Available online: https://matadornetwork.com/read/bali-tourist-tax-keep-island-pristine/ (accessed on 23.07.2019).

102. Willmott, L., Graci, S.R., 2012. Solid waste management in small island destinations: a case study of Gili Trawangan, Indonesia, 31, 3 (HS), Les innovations en tourisme durable, Available online: https://journals.openedition.org/teoros/1974 (accessed on 02.5.2019).

103. Beth, A. 2019, Venice tourists forced to pay to access Italian city in shock new holiday cost, Express, Available online: https://www.express.co.uk/travel/articles/1066641/venice-hotel-italy-tourist-tax-pay (accessed on 26.06.2019).

104. Stefano, C., Andrea, B., Rafael, L., 2016. Is taxing waste a waste of time? Evidence from a Supreme Court decision. Grantham Research Institute.

105. European Environmental Agency, 2016. Unsustainable consumption – the mother of all environmental issues? Available online: https://www.eea.europa.eu/highlights/unsustainable-consumption-2013-the-mother (accessed on 29.06.2019).

106. Ferrão, P., Ribeiro, P., Silva, P, 2008. A management system for end-of-life tyres: a Portuguese case study. Waste Management, Vol. 28, N.3, pp.604-14. DOI: 10.1016/j.wasman.2007.02.033.

107. Nahman, A., 2010. Extended producer responsibility for packaging waste in South Africa: Current approaches and lessons learned. Resources, Conservation and Recycling, Vol.54, N.3, pp.155-162. https://doi.org/10.1016/j.resconrec.2009.07.006.

108. Driedger, J.R., 2008. From cradle to grave: extended producer responsibility for household hazardous wastes in British Columbia, Journal of Industrial Ecology, Vol.5, No. 2, pp. 89-102 https://doi.org/10.1162/10881980152830150.

109. Charles, J.K., 2004. Extended producer responsibility: A tool for achieving sustainable development, Journal of land use, Vol.19, pp.2, Available online: https://www.researchgate.net/publication/265158179_Extended_producer_responsibility_A_tool_for_achieving_sustainable_development (accessed on 26.06.2019).

110. OECD, 2001. Extended producer responsibility a guidance manual for governments. Paris, France.

111. Walls, M., 2006. Extended producer responsibility and product design: economic theory and selected case studies. RFF Discussion Paper No. 06-08. Available online: https://ssrn.com/abstract=901661 or http://dx.doi.org/10.2139/ssrn.901661 (accessed on 26.06.2019).

112. UNEP, 2018. Draft practical manuals on Extended Producer Responsibility and on financing systems for environmentally sound management.

113. Pascal, R., Joachim, S., Jacky, L., Rabah, K., 2018. Reducing plastic waste leakage into waterways and oceans through circular economy and sustainable waste management, GIZ. Available online:https://www.giz.de/de/downloads/giz2018_marine-litter-prevention_web.pdf (accessed on 29.06.2019).

114. Bünemann, B., Brinkmann, J., Löhle, S., 2018. Extended producer responsibility (EPR) for managing packaging waste. GIZ Available online:

https://www.giz.de/de/downloads/giz2018_EPR-Packaging_web.pdf (accessed on 26.06.2019).

115. Yamini, G., Samraj, S., 2015. Review of extended producer responsibility: A case study approach. Waste Management & Research, Vol.33, No.7, pp. 595-611, DOI: 10.1177/0734242X15592275.

116. Abarca Guerrero, L., Mass, G., Hogland, W., 2012. Solid waste management challenges for cities in developing countries. Waste Management, Vol.33, pp. 220–232.

117. Kong, D., Shan, J., Lacobini, M., 2012. Evaluating greenhouse gas impact of organic waste management options using life cycle assessment. Waste Management & Research, Vol.30, pp. 800–812.

118. International Solid Waste Association., 2009. Waste and climate change, ISWA white paper. Available at: https://www.iswa.org/fileadmin/user_ upload/_temp_/WEB_ISWA_White_paper.pdf (accessed 25 August 2018).

119. Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste. Official J. L182 (1999) 1-19, Available online: https://ec.europa.eu/environment/waste/pdf/annexes_a1.pdf (accessed 25 August 2019).

120. Hüttl, R.F., Fussy, M., 2001. Organic matter management – a contribution to sustainability. Applying compost benefits and needs. Seminar Proceedings, Brussels, 22-23 Nov., 2001:9-17.

121. Weitz, K., Thorneloe, S.A., Nishtala, S.R., 2002. The impact of municipal solid waste management on greenhouse gas emissions in the United States. Journal of the Air and Waste Management Association, Vol. 52, pp. 1000–1011.

122. Turner, D.A., Williams, I.D., Kemp, S., 2015. Greenhouse gas emission factors for recycling of source-segregated waste materials. Resources, Conservation and recycling, resources, conservation and recycling, Vol. 105, pp. 186–197.

123. Sojobi, A.O., Nwobado, S.E., Aladegboye, O.J., 2016. Recycling of polyethylene terephthalate (PET) plastic bottle wastes in bituminous asphaltic concrete. Cogent Engineering, Vol. 3.

124. Todd, M., Hawkins, R., 2001. Waste counts: a handbook for accommodation operators. Centre for Environmental Studies in the Hospitality Industry. Oxford: Oxford Brookes University.

125. Pirani, S.I, Arafat,H.A., 2015. Reduction of food waste generation in the hospitality industry. Journal of Cleaner Production, Vol.132, DOI: 10.1016/j.jclepro.2015.07.146.

126.Ball, S., Taleb, M.A., 2011. Benchmarking waste disposal in the Egyptian hotel industry. Tourism and Hospitality Research, Vol.11, No.1, pp. 1-18. https://doi.org/10.1057/thr.2010.16.

127.Main, H., Chung, M., Ingold, A., 1997. A preliminary study of data utilization by small to medium sized hotels. International Journal of Contemporary Hospitality Management, Vol. 9, No.2/3, pp. 92-97.

128.Chen, M.C., Ruijs, A., Wesseler, J., 2005. Solid waste management on small islands: the case of Green Island, Taiwan. Resources, Conservation and Recycling, Vol.45, No.1, pp.31-47.

129.Shanklin, M.J, Carol, W, Petrillose, A.P., 1991. Solid waste management practices in selected hotel chains and individual properties. Journal of Hospitality & Tourism Research, Vol.15, No.1, pp. 59-74, DOI: 10.1177/109634809101500106.

130.Giurea, R., Precazzini, I., Ragazzi, M., Achim, M.I., Cioca, L.I., Conti, F., Torretta, V., Rada, E.C., 2018. Good practices for a sustainable municipal solid waste management. Resources, Vol. 7, pp.51.

131.Arbulu, I., Lozano, J., Rey-Maquieira, J., 2017. Waste generation flows and tourism growth: A STIRPAT Model for Mallorca. Journal of Industrial Ecology, Vol. 21, pp. 272–281.

132.Murava, I., Korobeinykova, Y., 2016. The analysis of the waste problem in tourist destinations on the example of Carpathian region in Ukraine. Journal of Industrial Ecology, Vol.17, pp. 43–44.

133.Greco, G., Cenciarelli, V.G., Allegrini, M., 2018. Tourism's impacts on the costs of municipal solid waste collection: Evidence from Italy. Journal of Clean Production, Vol.177, pp.62–68.

134.Edmundo, M., Rodrigo, N., 2015. Waste management in touristic regions. Waste Manag. Res, Vol.33, pp. 593–594.

135.Al-Khatib, I., Monou, M., Abu Zahra, A., Shaheen, H., Kassinos, D., 2010. Solid waste characterization, quantification and management practices in developing countries. A case study: Nablus district–Palestine. J. Environ. Manag, Vol.91, pp.1131–1138.

136.Foo, T., 1997. Recycling of domestic waste: Early experiences in Singapore. Habitat. Int, Vol. 21, pp. 277–289.

137.Bartone, C., 1990. Economic and policy issues in resource recovery from municipal solid wastes. Resources, Conservation and Recycling, Vol.4, pp. 7–23.

138. United Nations Environment Programme., 2005. World tourism organization, making tourism more sustainable: a guide for policy makers. Available online: https://www.unpei.org/sites/default/files/PDF/policyinterventions-

programmedev/Making-tourism-more-sustainableENpart1.pdf (accessed on 27.06.2019).

139. Liu, T.-K., Wang, M.-W., Chen, P., 2013. Influence of waste management policy on the characteristics of beach litter in Kaohsiung, Taiwan. Marine Pollution Bulletin. Vol.72, pp.99–106.

140. Estay-Ossandon, C., Mena-Nieto, A., 2018. Modelling the driving forces of the municipal solid waste generation in touristic islands. A case study of the Balearic Islands (2000–2030). Waste Management, Vol.75, pp.70–81.

141. Rada, E.C., Zatelli, C., Mattolin, P., 2014. Municipal solid waste selective collection and tourism. Waste Management and The Environment VII, Vol.180, pp.187–197.

142. Ranieri, E., Rada, E.C., Ragazzi, M., Masi, S., Montanaro, C., 2014. Critical analysis of the integration of residual municipal solid waste incineration and selective collection in two Italian tourist areas. waste management and research., Vol.32, pp. 551–555.

143. Gutierrez, E., Lamoureux, K., Matus, S., Sebunya, K., 2005. Conservation International, Linking Communities, Tourism & Conservation: A Tourism Assessment Process. Conservation International, George Washington University: Washington, DC, USA; ISBN 1-8811 73-43-7.

144. Shamshiry, E., Nadi, B., Mokhtar, B.M., Komoo, I., Hashim, S.H., Yahaya, N., 2011. Integrated models for solid waste management in tourism regions: Langkawi Island, Malaysia. Journal of Environmental and Public Health, Vol.9, pp.709-549.

145. Bohdanowicz, P., 2006. Environmental awareness and initiatives in the Swedish and Polish hotel: Industries—survey results. International Journal of Hospitality Management, Vol. 25, pp.662–682.

146. Mohan, V., Deepak, B., Mona, S., 2017. Reduction and management of waste in hotel industries. Int. Journal of Engineering Research and Application, Vol.7, pp.34–37.

147. Bahia, S.R., 1995. Sustainability indicators for a waste management approach research project report of the Msc course on environmental pollution control. University of Leeds: Leeds, UK.

148. Kirk, D., 1998. Attitudes to environmental management held by a group of hotel managers in Edinburgh. Hospitality Management, Vol.17, pp.33–47.

149. Erdogan, N., Baris, E., 2007. Case study environmental protection programs and conservation practices of hotels in Ankara, Turkey. Tourism. Management. Vol.28, pp.604–614.

150. María, D.L., Enrique, C.C., José, F.M.A., 2011. Environmental perception, management, and competitive opportunity in Spanish hotels. Cornell Hospitality Quarterly. Vol.52, pp.480–500.

151. Philips, A., 2014. Greening hotels: the case of solid waste management by chain hotels and individual properties in Sofia. Master Thesis, Cardiff Metropolitan University, International University College, Sofia, Bulgaria.

152. Tang, J., 2004. A case study of a hotel solid waste management program in Bali, Indonesia. Master Thesis, Master of Environmental Studies in Planning, Waterloo, ON, Canada. Available online: https://www.collectionscanada.gc.ca/obj/s4/f2/dsk3/OWTU/TC-OWTU-373.pdf (accessed on 2 August 2018).

153. Ezeah, C., Fazakerley, J., Byrne, T., 2015. Tourism waste management in the European Union: lessons learned from four popular EU tourist destinations. American Journal of Climate Change, Vol.4, pp.431–445.

154. Walter, J., Amit, K., Sunalai, P., Pallavi, M., 2003. A manual for water and waste management: what the tourism industry can do to improve its performance. United Nations Environment Programme, Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH: Bonn, Germany, 2003; UNEP, United Nations Publication, ISBN: 92-807-2343-X.

155. WRAP (Waste & Resources Action Programme), 2018. Cost-Effective Management of Organic Waste from the Food and Drink and Hospitality Sectors. International Tourism Partnership, UK. Available online: http://www.greenhotelier.org/wp-content/uploads/2014/09/Know-How-Guide-on-Managing-and-Reducing-Food-Waste.pdf (accessed on 2 August 2018).

156. Vilms, M., Voronova, V., 2016. Non-deposit system option for waste management on small islands. Waste Management and Research, Vol.34, pp.748–754.

157. Alejandro, B., Juan, D.H., Macht, A., Rodríguez, M., 2008. Public-Private Partnerships as a means to consolidate integrated solid waste management initiatives in tourism destinations: the case of the Mexican Caribbean. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), Bonn, Germany.

158. Cuellar, S., 2008. Market analysis of solid waste collection, recycling and reuse in the tourism sector of the municipalities of Benito Juárez and Solidaridad of the State of Quintana Roo. GTZ, Quintana Roo, Mexico.

159. Florin, M., 2013. Tourism implications on local waste management: Case study: Neam County, Romania. Present Environment and Sustainable Development, Vol.7, pp.214–221.

160. Styles, D., Schönberger, H., Galvez, M., 2013. Best Environmental Management Practice in the Tourism Sector; European Commission: Brussels, Belgium; Luxembourg City.

161. Gidarakos, E., Havas, G., Ntzamilis, P., 2006. Municipal solid waste composition determination supporting the integrated solid waste management system in the island of Crete. Waste Management, Vol.26, pp.668–679.

162. Pirani, S.I., Hassan, A.A., 2014. Solid waste management in the hospitality industry: A review. Journal of Environmental Management, Vol.146, pp. 320–336.

163. Ghribi, K., 2012. Programme Pilote de Gestion Intégrée des Déchets à l'île de Djerba (PGIDID): Analyse déchets de l'hôtel Dar Djerba, Published by ACR+MED, Djerba, Tunisia.

164. Daniel, H., Perinaz, B.T., 2012. The world bank, What a waste, a global review of solid waste management, Available online: documents.worldbank.org/curated/en/302341468126264791/pdf/68135-REVISED-What-a-Waste-2012-Final-updated.pdf (accessed on 29.06.2019).

165. Diagnostic de la gestion des déchets à Djerba Houmt Souk (Tunisie), Available online: http://www.acrplus.org/images/publication/ACRMED/Diagnostic_reviews/DiagnostiDjerba.pdf (accessed on 29.06.2019).

166. Okazaki, W.K., Turn, S.Q., Flachsbart, P.G., 2008. Characterization of food waste generators: A Hawaii case study. Waste Management, Vol.28, pp.2483–2494.

167. Pirani, S.; Arafat, H.A., 2016. Reduction of food waste generation in the hospitality industry. Journal of clean production. Vol.132, pp.129–145.

168. Favro, S., Brebbia, C.A., 2013. Island Sustainability II, Second International Conference on Island Sustainability; WIT Press: Southampton, UK.

169. Chapelle, S., Gouin, S., 2015. Observatoire des Multinationales. Available online: http://multinationales.org/Dechets-la-face-cachee-du-tourisme-de-masse-en-Tunisie (accessed on 26 October 2018).

170. Phu, P., Hoang, M.G., Fujiwara, T., 2018. Analyzing solid waste management practices for the hotel industry. Global Journal of Environmental Sciences and Management. Vol.4, pp.19–30.

171. Hackes, B.L., Shanklin, C.W., Kim, T., Su, A.Y., 1997. Tray service generates more food waste in dining areas of a continuing-care retirement community. J. Am. Diet. Assoc, Vol.97, pp.879–882.

172. Torretta, V., Salazar-Valenzuela, X., 2014. Management of municipal solid waste in one of the Galapagos Islands. Sustainability, Vol. 6, pp.9080–9095.

173. DO, T.T.T., 2016. A study of solid waste generation from commercial and institutional sectors and its potential for recovery in Vietnam, PhD Thesis, Graduate School of Environmental and Life Science, Okayama University. Available online: http://ousar.lib.okayama-u.ac.jp/files/public/5/54659/20170309184851938253/O0004462_fulltext.pdf (accessed on 06.10.2018).

174. SWEEP-Net Report., 2014. Report on the solid waste management in Tunisia, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). Available online:

http://www.retech-germany.net/fileadmin/retech/05_mediathek/laenderinformationen/Tunesien_laenderprofile_sweep_net.pdf (accessed on 25.06.2019).

175. Lu, J., Nepal, S.K., 2009. Sustainable tourism research: an analysis of papers published in the Journal of Sustainable Tourism, Journal of Sustainable Tourism, Vol.17, N.1, pp.5-16, DOI: 10.1080/09669580802582480.

176. Antonis, A.Z., Irene, V., Pantelitsa, L., 2015. The impact of tourist sector in the waste management plans. Desalination and water treatment, Vol.56, pp.1141-1149. https://doi.org/10.1080/19443994.2014.934721.

177. Najdeska, A.K., Rakicevik, G., 2012. Planning of sustainable tourism development. Procedia, Social and Behavioral Sciences, Vol. 44, pp. 210-220, https://doi.org/10.1016/j.sbspro.2012.05.022.

178. Dileep, M. R., 2007. Tourism and waste management: a review of implementation of "Zero Waste" at Kovalam. Asia Pacific Journal of Tourism Research, Vol 12, N.4, https://doi.org/10.1080/10941660701823314.

179. Glenn, K., 2001. The Impacts of Tourism. Available online: http://www.seagrant.umn.edu/tourism/pdfs/ImpactsTourism.pdf (accessed on 27.06.2019).

180. Christer, B., 2003. Economic efficiency in waste management and recycling. Lulea University of Technology, Department of Business Administration and Social Sciences Division of Economics, Doctoral thesis, Available online: https://www.diva-portal.org/smash/get/diva2:991099/FULLTEXT01.pdf (accessed on 27.06.2019).

181. Prabhakar, R.P., Sanket, S., Rahul, B.P, 2016. Plastic marine debris: sources, distribution and impacts on coastal and ocean biodiversity. PENCIL Publication of Biological Sciences, Oceanography, Vol. 3. N.1, pp. 40-54. (ISSN: 2408-5561). Available online: https://www.researchgate.net/publication/295919494 (Accessed on 27.06.2019).

182. Marine Litter Solutions, 2019. Available online: https://www.marinelittersolutions.com/about-marine-litter/what-causes-marine-litter/ (accessed on 10 March 2019).

183. Tyrrell, T., 1992. Tourism and the environment: marine debris, beach pollution and the importance of image. In Proceedings of the Second Marine Debris Workshop Conference, Merida, Mexico, pp.17–19.

184. Arif, S., Doumani, F., Abdeljaouad, I., 2015. Cost of environmental degradation due to solid waste management practices, case of Djerba Island. Unpublished work.

185. Hoang, M.G., 2017. A study on development methodology of sustainable solid waste management system by using multi-objective decision making model - a case study

in Hoi An City, Vietnam. Ph.D. Thesis, Graduate School of Environmental and Life Science Okayama University, Okayama, Japan.

186. En, L., Konstantinos, M., Dimitrios, P., Dimitrios, P.K, Asimina E.D., Vayos, G.K., 2017. Sustainable solid waste management: Socio-economic considerations. Chemical Engineering Transactions, Vol.56, pp.661-666, DOI: 10.3303/CET1756111.

187. Ernest, R.A, 1982. Design in the decision-making process. Elsevier Scientific Publishing Company, Amsterdam, Vol.14, N. 3, pp.279-292.

188. Fanack. 2019. Economy of Tunisia. Available online: https://fanack.com/tunisia/economy/ (accessed on 3 February 2019).

189. Agnes, B., Sabine, B., Abdallah, N., 2018. Extended producer responsibility in the MENA region. Unpublished work.

190. Fleckinger, P., Glachant, M., 2010. The organization of extended producer responsibility in waste policy with product differentiation. Journal of Environmental Economics and Management, Elsevier, Vol.59 N.1, pp.57-66. 10.1016/j.jeem.2009.06.002. hal-00446819.

191. European Commission – DG Environment, 2014. Development of guidance on extended Producer Responsibility (EPR). Available online: http://ec.europa.eu/environment/waste/pdf/target_review/Guidance%20on%20EPR%20-%20Final%20Report.pdf (accessed on 11.07.2019).

192. OECD, 2016. Extended producer responsibility—guidance for efficient waste management. Paris, France.

193. OECD, 2013. What have we learned about extended producer responsibility in the past decade?—A survey of the recent EPR economic literature. Paris, France.

194. Cyclos GmbH, 2019

195. Herdiana, D. S., Pratikto, Sudjito, S., Fuad, A., 2014. Policy of extended producer responsibility (case study). International Food Research Journal, Vol. 21, N.3, pp.873-881.

196. Storino F., Arizmendiarrieta J.S., Irigoyen I., Muro J., Aparicio – Tejo P.M., 2016. Meat waste as feedstock for home composting: Effects on the process and quality of compost. Waste Management, Vol. 56, pp. 53 – 62, Elsevier Science Publisher.

197. Oazana, S. H., Naor, M., Grinshpun, J., Halachmi, I., Raviv, M., Saadi, I., Laor, Y., 2018. A flexible control system designed for lab-scale simulations and optimization of composting processes. Waste Management, Vol. 72, pp.150-160.

198. Onwosi, C., Igbokwe, V., Odimba, J., Eke, I., Nwankwoala, M., Iroh, I., Ezeogu, L., 2017. Composting technology in waste stabilization: On the methods, challenges and future prospects. Journal of Environmental Management, Vol.190, pp.140–157.

199. Khelifi, R.; The Arab Weekly, 2018. Tunisia's coastal town of Gammarth: A perfect blend of luxury and nature. Available online: https://thearabweekly.com/tunisias-coastal-town-gammarth-perfect-blend-luxury-and-nature.

200. CIWMB., 2007. Compost use for landscape and environmental enhancement. California, USA: California Environmental Protection Agency, the California Integrated Waste Management Board.

201. USCC., 2001. Field guide to compost use. US composting council, E&A Environmental Consultants, Inc., USA.

202. Rynk, R., van de Kamp, M., Willson, G., Singley, M., Richard, T., Kolega, J., Gouin, F., Brinton, W., 1992. On-farm composting handbook. Ithaca, New York: Natural Resource, Agriculture, and Engineering Service (NRAES).

203. Poincelet, R., 1977. The biochemistry of composting. In Composting of municipal sludges and wastes. Proceedings of the National Conference, Rockville, Maryland, pp.33–39.

204. Willson, G., 1993. Combining raw materials for composting. In J. Goldstein (Ed.), The biocycle guide to yard waste composting (pp. 102-105). Emmaus, Pennsylvania: The JG Press.

205. Bunt, A.C., 1988. Media and mixes for container-grown plants (2nd ed). London, UK: Unwin Hyman Ltd.

206. Hemidat, S., Jaar, M., Nassour, A., Nelles, M., 2017. Monitoring of composting process parameters: A case study in Jordan. Waste and Biomass Valorisation, Vol.9, pp.2257–2274.

207. Abbassi, B., Abubaker, S., Al-Manaseer, E., Nassour, A., Dababneh, B., Shqairat, W., Al-Jaar, M., 2015. Optimization of operating parameters of windrow composting of animal manures. Journal of Solid Waste Technology and Management, Vol.41, pp.60–67.

208. Ouédraogo, E., Mando, A., Zombré, N.P., 2001. Use of compost to improve soil properties and crop productivity under low input agricultural system in West Africa. Journal of Agricultural Ecosystems and Environment, Vol.84, pp.259–266.

209. BioAbfV, 2017. Ordinance on the recovery of biowaste on agricultural, forestry and horticultural uses. (Biowaste Ordinance - BioAbfV). Available online: https://www.gesetze-im-internet.de/bioabfv/BioAbfV.pdf (accessed on 29.06.2019).

210. Komilis, D.P., Ham, R.K., 2003. The effect of lignin and sugars to the aerobic decomposition of solid wastes. Waste Management, Oxford, Vol.23, pp.419–423.

211. Garcia, C., Hernandez, T., Costa, F., Ceccanti, B., Ciardi, C., 1992. Changes in ATP content, enzyme activity and inorganic nitrogen species during composting of organic wastes. Canadian Journal of Soil Science, Vol.72, pp.243–253.

212.Masau, P.,Prideaux, B. (2003). Sustainable tourism: A role for Kenya's hotel industry.current issues in tourism, 6(3), 197-208. ttps://doi.org/10.1080/13683500308667953.

Appendix I: Key indicator development for SWM in tourism destinations

Annex I.1. Support of municipal cleaning and waste collection activities by the MALE (Source: MALE)

Tourism municipality	Solid waste collection	Manual sweeping/cleaning	Mechanical sweeping/cleaning
Tunis		×	
Bardo	×		×
Carthage	×		×
Sidi Bousaid		×	×
La Goulette		×	×
Kram	×		×
Bizerte	×	×	
Hammamet			×
Nabeul	×	×	×
Sousse	×	×	×
Hammam Sousse			×
Mehdiya		×	×
Mounastir	×	×	×
Kairouan	×	×	
Sfax	×	×	×
Touzeur	×	×	
Kef		×	
Tataouine		×	
Kebeli		×	
Djerba			×
Zarzis	×		
Kelibia		×	

Annex I.2: Questionnaire for Hotels: Evaluation of hotels' waste management systems

- Name of the hotel
- Category
- Address/governorate
- Year of construction
- Contact person
- E-mail
- Certification/standards

GENERAL QUESTIONS

- Number of rooms
- Number of beds
- Average occupancy
- Peaks and low values during high and low season
- Employees (total)

WASTE MANAGEMENT

Satisfactions	**Yes**	**No**
Are you satisfied with the waste management system in this tourist area?	❒	❒
Are you satisfied with the waste management system around the hotel?	❒	❒

- Where are the waste collection bins placed? Special place ❒ In the garden ❒ Outside ❒
- Is the size of the waste collection bins suitable?
- What is the food service offered in your hotel? Buffet ❒ Menu ❒
- What types of waste are collected separately in your hotel?
  Organic ❒ Paper ❒ Plastic ❒ Metal ❒ Glass ❒ Others ❒
- How much do you pay per month/year for fertilisers (garden)?
- How much fertiliser do you use (Kg) per month/year? Specify the number of cleaning/waste management staff? Male ❒ Female ❒
- Do you have cleaning contractors?
- Frequency of waste collection from rooms/day? 1 ❒ 2 ❒ More ❒

Waste Management Monitoring	**Yes**	**No**
The solid waste generation, specifically the quantity and composition, is regularly monitored in your hotel.	❒	❒
The kitchen waste is regularly monitored in your hotel.	❒	❒
There is a register of data for the solid waste generated per room (per client).	❒	❒
Are the staff involved in the development of strategies for waste minimisation, segregation and collection?	❒	❒
In the hotel, is there a person responsible for, and an implementation timetable of, activities to reduce waste?	❒	❒

Is there a plan in your establishment that identifies targets for reducing the amount of waste? If Yes, what are the identified activities?	❒	❒

Inorganic Waste Management	**Yes**	**No**
The company has suitable containers for sorting garbage (aluminium, plastic, glass and paper).	❒	❒
Room service staff sort the garbage when the client does not.	❒	❒
There is an equipped place in which the final waste sorting is carried out.	❒	❒
Are you collecting batteries separately?	❒	❒
The hotel participates in a recycling programme in which they duly sort waste.	❒	❒
Are you sending your electrical and electronic waste to a service provider who recycles and removes it cleanly?	❒	❒
Are you sending your used printer cartridges to recycling sites that recycles and eliminate them cleanly?	❒	❒

Final Provision	**Yes**	**No**
Solid waste produced by the hotel is stored appropriately before final collection.	❒	❒
The hotel verifies and guarantees that the collection and final disposal of waste is carried out efficiently.	❒	❒

Staff Training on Waste Management	Yes	No
Hotel staff know what happens with the collected waste.	❒	❒
The hotel has an apprenticeship programme for the collection and sorting of waste.	❒	❒
There is staff training at least once a year on SWM.	❒	❒

Annex I.3. Questionnaire for municipalities

Name of the municipality, address/governorate, tourism destination, position of the person in charge of the questionnaire, contact person.

Waste management in your tourist area

- Total waste generated in your tourism destination (ton/year)
- Cost of waste collection in your tourism destination
- Percentage of the collection costs compared to the municipality budget
- How many hotels exist in your tourism area?
- How is solid waste collected? Public sector ❒ Private sector ❒ Both ❒
- If both, what is the percentage for each sector?
- Quantities of waste generated from hotels and restaurants in your tourism destination
- Do you have a composting initiative in your tourism destination? If yes, what is the composted amount?
- If you have a beach, how is the cleaning organised (weekly, monthly?)?
- Who is cleaning the beaches?
- Is the cleaning done manually or is it automated?
- Annual cost of road and beach cleaning in your tourism destination (estimation)

Waste collection by the public sector (municipality)

- What is the cost of waste collection (per ton) by the public sector in your tourist area?
- What is the frequency of waste collection from hotels and restaurants (week)?
- What are the encountered problems when collecting waste from hotels?
- What kind of waste do you collect from hotels? Is green waste also collected?

Waste collection by the private sector

- What is the waste collection cost (per ton) by the private sector in your tourist area?
- Is it done by: Large collection companies ❒ Small collection companies ❒ Both❒
- What is the duration of signed contracts with private collection companies?
- What types of private recycling/sorting companies exist? How many are there?
- Do you cooperate with them (as a municipality)? How?
- Do you cooperate with tourism organisations (FTAV, FTH, Ministry of Tourism)?

Hotel taxes

- Do you think that the hotel tax (1% of the turnover for the municipalities) can cover the expenses of the municipality as regards to SWM of hotels? Explain.
- Do you apply a tax on restaurants for waste collection?
- Do you benefit from the tourism fund? If so, how much (in TND) per year?

Fate of the waste after collection

- What is the destination of waste after collection from hotels (valorisation? landfilling? dumpsite?)
- Are there any initiatives for waste sorting/recovery in hotels? If yes, in how many hotels?

Annex I.4. Questioned hotels in tourism destinations

Tourist destination	Name of the hotel	Stars	Number of rooms	Number of beds
Bizerte	Andalousiya	4	41	82
	Bizerta Resort	4	104	208
Tunis	Concord Lac 1	5	159	258
	Dar El Marsa	5	29	60
	Golden Tulipe Gammarth	5	265	500
	Ramada Plaza	5	309	500
	The Residence	5	155	320
	Acropole Lac 1	4	80	160
	Hotel Paris Lac 1	4	75	140
	Hotel Tiba	3	47	74
Nabeul - Hammamet	Hotel Mouradi	5	377	754
	Resselior	5	237	474
	Syndibad	5	154	330
	Radisson Blu	5	320	540
Jendouba	Les Pins	1	23	60
Sousse	Hotel Marhaba Beach	4	286	530
	Hotel Marhaba Royal Salem	4	164	350
	Eden Yasmine Resort, Spa & Golf Services	4	156	312
Mounastir	Royal Ruspina	4	303	750
Sfax and Kerkennah	Golden Tulip	5	130	260
	Borj Dhiafa	5	50	100
	Zitouna	5	260	260
	Syphax	4	127	257
	Grand Hotel	4	100	185
Kairouan	Hotel la Kasbah	5	96	210
	Hotel Continental	3	106	212
	Hotel Amina	3	105	205
	Hotel Splendid	1	37	80
	Hotel Tunisia	1	42	76
Djerba - Mednine	Hotel Mouradi	4	636	1,272
	Hotel Palm Azur	4	391	870
	Club Calimera Yati Beach	4	336	672
	Odyssee Resort	4	344	688
	SENTIDO Djerba Beach	4	246	517
	TELEMAQUE BEACH & SPA – DJERBA	4	216	224
	Hotel Aljazira Beach & Spa - Djerba	3	275	550

Annex I.5. Results of the characterisation of waste in four hotels kitchens in Gammarth

Hotel / Type of waste	Hotel 1: Ramada			Hotel 2: Movenpick			Hotel 3: Mouradi			Hotel 4: Le Palace			Average	%
	Breakfast (BF)	Lunch (L)	Dinner (D)	BF	L	D	BF	L	D	BF	L	D		
Cleaning dishes														
Organic waste	103.1	179.3	28.6	45,5	64.9	26.9	19.7	9.6	4.3	74.8	102	133,9	122,2	83
Paper	19.1	10.8	3.9	13,5	3.5	1.5	18.6	5.9	10.5	6.5	4	9.5	8.8	6
Plastic	18.15	6.2	4.871	6,1	6.2	3.2	5.6	11.3	2.3	2.4	2.3	8.6	7.7	5
Glass	5.32	3.66	1.52	0,51	1.5	3.5	3.8	1.2	1.8	1.2	1.9	6.3	3.7	3
Metal	1.2	0.078	0.11	0,5	0.69	0.1	248.9	266.3	303.8	0.77	0,6	5.87	1.4	1
Total	148.7	201.2	46.2	66,1	78.3	35.2	195.1	233.6	278.1	87.9	113	164.3	146,7	100
Preparation														
Organic waste	48.7	95.6	17.3	17.5	42	20.6	71.5	122.7	99.6	36.2	62.9	97.2	61.0	63
Paper	12.3	18.6	6.2	9.2	8	5.2	21.7	25.6	12.9	9.3	4.8	12.3	12.2	12
Plastic	10.9	20.9	5.6	9.7	15.6	9.6	26.9	13.5	14.2	6.9	6.9	10.2	12.5	13
Glass	3.7	12.3	7.1	2.5	3.9	4.9	8.9	18.3	9.6	3.7	5.2	7.2	7.3	7
Metal	0.5	0.3	0.3	0.4	0.8	0.9	2.7	0.9	3.6	2.2	2.1	2.7	4.9	5
Total	76.2	147.7	36.5	39.4	71.9	41.2	131.9	183.5	148.3	60.7	85.3	137.9	96.7	100
Return														
Organic waste	14.7	6.3	1	7.2	15.2	-	-	-	-	-	-	-	10.9	91.2
Paper	1.3	-	-	2.9	-	-	-	-	-	-	-	-	2.1	17.5
Plastic	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Glass	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	16.0	6.3		10.1	15.2								11.9	100

Annex I.6. General information on solid waste management in 19 tourism destinations in Tunisia

Municipality	Governorate	Tourist destination	Total waste generated (year)	Cost of waste collection (year)	% from municipal budget	Number of hotels	Collection by private/public	% of private or/and public
Djerba Houmet Souk	Medenine	Djerba	-	-	-	23	Both	100 % private during summer
Bardo	Tunis	Bardo	29,200 tons	1,839.600 TND	21%	0	Both	37% private/63% public
Tamaghza	Touzeur	Tamaghza, Chbika, Mides	1,872 tons	280,000 TND	25%	1	Public	100% public
Djerba Ajim	Medenine	Djerba	5,040 tons	469,563 TND	25.7%	0	Both	92% public/8% private
Matmata	Gabes	Matmata	1,000 tons	100,000 TND	25%	5	Both	60% public/40% private
Djerba Midoun	Medenine	Djerba	20,000 tons	2,700.000 TND	43%	74	Both	60% public/40% private
Touzeur	Touzeur	Touzeur	25,550 tons	1,450.000 TND	20%	33	Both	70% public/30% private
Bizerte	Bizerte	Sidi Salem	54,000 tons	2,970.000 TND	25%	9	Both	87% public/13% private
Ben Gerdane	Mednine	Marsa Ksiba	14,600 tons	1,166.276 TND	40%	3	Public	100% Public
Hammam Sousse	Sousse	Kantaoui-Hammam Sousse	24,000 tons	1,600.000 TND	13.6%	32	Public	100% Public
Sousse	Sousse	Boujaafar	75,000 tons	4,700.000 TND	23%	67	Both	70% private/30% public
Hammamet	Nabeul	Hammamet	38,000 tons	2,000.000 TND	20%	104	Both	-
Marsa	Tunis	Marsa - Gammarth	37,000 tons	4,850.000 TND	30%	17	Both	50% private/50% public
Monastir	Monastir	Skanis, Monastir, Medina	13,160 tons	2,500.000 TND	15%	48	Both	60% private/30% public
Sahline - Moutamar	Mounastir	Sehlin Moutamar	3,600 tons	500,000 TND	25%	0	Both	40% private/60% public
Chenini - Nahal	Gabes	Chenini, Nahal	3,500 tons	16,000 TND	18%	4	Public	100% Public
Kerkennah	Sfax	Kerkennah	6,000 tons	250,000 TND	6.3%	10	Both	70% public/30% private
Korbos	Nabeul	Korbos	5,000 tons	300,000 TND	50%	4	Public	100% public
Sekanis	Monastir	Sekanis	3,600 tons	1,500.000 TND	20%	48	Both	60% private/40% public

Annex I.7. General information on SWM in 19 tourism destinations in Tunisia

Municipality	Waste generation from tourism establishments (year)	Composting in the municipality	Composted quantities (Year)
Djerba Houmet Souk	-	Yes	2 tons of bio-waste/green waste per day
Bardo	1,460 tons	No	No composting initiatives recorded
Tamaghza	80 tons	No	No composting initiatives recorded
Djerba Ajim	7 tons	No	No composting initiatives recorded
Matmata	40 tons	No	No composting initiatives recorded
Djerba Midoun	800 tons	No	No composting initiatives recorded
Touzeur	2,555 tons	Yes	Just started – 1,000 tons green waste
Bizerte	4,000 tons	Yes	Just started – 2,000 tons per year
Ben Gerdane	365 tons	Yes	2 tons of bio-waste/green waste
Hammam Sousse	6,000 tons	No	No composting initiatives recorded
Sousse	7,000 tons	No	No composting initiatives recorded
Hammamet	20,000 tons	No	No composting initiatives recorded
Marsa	9,000 tons	Yes	30 tons of green waste per year
Monastir	7,000 tons	No	No composting initiatives recorded
Sahline - Moutamar	100 tons	Yes	200 kg/year
Chenini - Nahal	220 tons	No	No composting initiatives recorded
Kerkennah	120 tons	No	No composting initiatives recorded
Korbos	500 tons	No	No composting initiatives recorded
Sekanis	10,800 tons	No	No composting initiatives recorded

Annex I.8. Cleaning activities and costs in 19 tourism destinations in Tunisia

Municipality	Frequency of cleaning actions on beaches	Who is cleaning the beaches	Beach cleaning manually/mechanically	Cost of street and beach cleaning (Year)
Djerba HS	Monthly/daily during the summer	Municipality and APAL	APAL: mechanically/municipality: manually	-
Bardo	No beaches	No beaches	No beaches	-
Tamaghza	No beaches	No beaches	No beaches	-
Djerba Ajim	Monthly	Municipality	Manually	6000 TND
Matmata	No beaches	No beaches	No beaches	20,000 TND for streets
Djerba Midoun	Monthly/daily during the summer	Municipality and APAL	APAL: Mechanically /Municipality: manually	100,000 TND
Touzeur	-	-	-	-
Bizerte	Seasonal/daily during the summer	Municipality and APAL	Both	330,000 TND
Ben Gerdane	Monthly	Municipality	Both	200,000 TND
Hammam Sousse	Every week winter/daily summer	Municipality and APAL	Both	70,000 TND
Sousse	Daily	Municipality and private sector	Both	1,000.000 TND
Hammamet	Seasonal/daily from May	Private sector and APAL	Both	140,000 TND
Marsa	Frequency 170 day/year	Municipality and APAL	Both	1,828.691 TND
Monastir	Daily during the summer	Private sector	Manually	40,000 TND
Sahline – Moutamar	-	-	-	-
Chenini – Nahal	-	-	-	-
Kerkennah	Monthly	Municipality	Manually	20,000 TND
Korbos	Daily	Municipality	Manually	100,000 TND
Sekanis	Seasonal	Private sector	Manually	120,000 TND

Annex I.9. Public sector role in SWM in tourism destinations in Tunisia

Municipality	Public sector collection costs (per ton)	Frequency of collection from tourism establishments	Problems during the collection	Type of waste collected from hotels/Green waste included.
Djerba HS	55 TND	1 time/day	Very humid waste, inadequate containers	Only residual waste
Bardo	92,600 TND	2 time/day	Timing of waste disposal	Residual and green waste
Tamaghza	149 TND	1 time/day	-	Residual waste and other waste
Djerba Ajim	-	1 time/day	-	Organic waste
Matmata	100 TND	1 time/day	Bad infrastructure	Organic waste and others
Djerba Midoun	90 TND	1 time/day	No sorting, lack of adequate containers	Residual waste
Touzeur	135 TND	1 time/day	Waste collection method	Other waste
Bizerte	55 TND	1 - 2 time/day	Hotels: lack of containers and absence of collection local in some hotels Restaurants: waste disposal in collective containers	Residual waste only
Ben Gerdane	120 TND	1 time/day	No sorting, lack of adequate containers	Residual and green waste
Hammam Sousse	58 TND	1 - 2 time/day	No sorting, lack of adequate containers, high amount of waste during the summer	Residual waste only
Sousse	60 TND	1 time/day	Inadequate collection of waste, lack of containers	Residual waste only
Hammamet	80 TND	1 time/day	Broken containers, inadequate collection	Residual and organic waste
Marsa	65 TND	1 time/day	Lack of containers	Residual waste and green waste
Monastir	69 TND	1 time/day	Lack of containers, inadequate space for containers	Residual waste only
Sahline - Moutamar	190 TND	1 time/day	-	-
Chenini - Nahal	114 TND	1 time/day	Inadequate containers	Residual and green waste
Kerkennah	70 TND	1 time/day	Lack of workers, timing of waste disposal	Residual waste only
Korbos	60 TND	1 time/day	-	Residual and green waste
Sekanis	30 TND	1 time/day	Lack of containers, inadequate waste containers space	Residual waste only

Annex I.10. Private sector role in SWM in tourism destinations in Tunisia

Municipality	Collection costs (TND/ ton)	Type of private companies	Contract duration	Private collection/ recycling companies	Collaboration with these companies
Djerba HS	55	Small companies	3 months	1	No
Bardo	63	Big companies	3 years	1 (collection)	Yes
Tamaghza	-	-	-	-	No
Djerba Ajim	80	Small companies	6 months	1 (collection)	Yes
Matmata	150	Small companies	-	-	No
Djerba Midoun	500 (due to the SWM crises in the island)	Small companies	5 years collection/ 3 years cleaning	3	Yes
Touzeur	55	Big companies	3 years	3 plastic bottles collection	Yes
Bizerte	62	Big companies	3 years	1 paper, 1 glass, 1 plastic, 3 plastic recycling, 1 metals, 1 tires	Yes
Ben Gerdane	-	-	-	-	No
Hammam Sousse	-	-	-	16	Yes
Sousse	52	Big companies	5 years	2	No
Hammamet	70	Big companies	5 years/3 years	2	Yes
Marsa	45.7	Both small and big companies	5 years	5	No
Monastir	60	Both small and big companies	3 years / 3 months	-	Yes
Sahline - Moutamar	62	Small companies	1 year	-	No
Chenini – Nahal	-	-	-	-	No
Kerkennah	50	Small companies	3 months	-	No
Korbos	-	-	-	-	No
Sekanis	40	Both small and big companies	3 years / 3 months	1 (collection)	Yes

Appendix II: Monitoring of composting process parameters from kitchen waste and green waste generated in tourism destinations

Annex II.1. Results of the dosage of major elements in green waste composting (start of the cycle) carried out in Tunisia

DIRECTION DU LABORATOIRE	Fiche suiveuse	Codification : EC-V.9/01-EMB Date de création : 12/02/18 Version: a

Dosage des éléments majeurs

Dosage de 33 éléments par spectroscopie d'émission atomique avec plasma couplé par induction selon la norme ISO 11885, AOUT 2007

Opérateur :
Date d'exécution:
Signature:

Date de réception : début du cycle
Nature de l'échantillon:

Ech	Elément	% MS	V_0	Prise d'essai	Dilution	Lecture échant.	Lecture Blanc	[C]
DV			ml	g		mg/l	mg/l	(g/KgMS)
	Calcium	94	50	0,502	10	49,49	0,0052	52,43
	Magnésium	94	50	0,502	10	2,44	0	2,59
	Sodium	94	50	0,502	10	1,48	0	1,57
	Potassium	94	50	0,502	10	9,32	0,145	9,72
	Phosphore	94	50	0,502	10	2,05	0,025	2,15
					MR		Intervalle	
MR Ca	100mg/l				97,15	95 - 105		
MR Mg	100mg/l				96,38	95 - 105		
MR Na	100mg/l				93,77	95 - 105		
MR K	100mg/l				98,17	95 - 105		
MR P	100mg/l				98,25	95 - 105		

Observation:

La formule :

$$C\ (g/kg_{MS}) = \frac{([\text{Lecture Ech} - \text{Lecture Blanc}] * V0 * \text{dilution})/1000}{M * \%MS/100}$$

%MS pourcentage de la matière sèche
V_0: Volume en millilitres de l'echantillon à doser
Lecture Echantillon: c'est la concentration obtenue du l'echantillon
Lecture Blanc: c'est la concentration obtenue du blanc

Validation n°:
Unité:
Nom et prénom:
Date de validation:
Signature:

Remise de la fiche suiveuse à la réception
Nom et prénom:
Date:
Signature:

Annex II.2. Results of the dosage of major elements in green waste composting (end of the cycle) carried out in Tunisia

DIRECTION DU LABORATOIRE	Fiche suiveuse	Codification : EC-V.9/01-EMB Date de création : 12/02/18 Version: a

Dosage des éléments majeurs

Dosage de 33 éléments par spectroscopie d'émission atomique avec plasma couplé par induction selon la norme ISO 11885, AOUT 2007

Opérateur :
Date d'exécution:
Signature:

Date de réception : Fin du cycle
Nature de l'échantillon:

Ech	Elément	% MS	V_0	Prise d'essai	Dilution	Lecture échant.	Lecture Blanc	[C]
DV			ml	g		mg/l	mg/l	(g/KgMS)
	Calcium	94	50	0,511	10	71,86	0	74,80
	Magnésium	94	50	0,511	10	5,077	0,514	4,75
	Sodium	94	50	0,511	10	2,73	0	2,84
	Potassium	94	50	0,511	10	11,66	0,346	11,78
	Phosphore	94	50	0,511	10	2,98	0,242	2,85
					MR		Intervalle	
MR Ca	100mg/l				98,12	95 - 105		
MR Mg	100mg/l				95,36	95 - 105		
MR Na	100mg/l				93,67	95 - 105		
MR K	100mg/l				99,16	95 - 105		
MR P	100mg/l				96,08	95 - 105		

Observation:

La formule :

$$C\ (g/kgMS) = \frac{([\text{Lecture Ech} - \text{Lecture Blanc}] * V0 * \text{dilution})/1000}{M * \%MS/100}$$

%MS pourcentage de la matière sèche
V_0: Volume en millilitres de l'echantillon à doser
Lecture Echantillon: c'est la concentration obtenue du l'echantillon
Lecture Blanc: c'est la concentration obtenue du blanc

Validation n°:
Unité:
Nom et prénom:
Date de validation:
Signature:

Remise de la fiche suiveuse à la réception
Nom et prénom:
Date:
Signature:

Annex II.3. Results of the dosage of major elements in kitchen organic waste composting (start of the cycle) carried out in Tunisia

DIRECTION DU LABORATOIRE	Fiche suiveuse	Codification : EC-V.9/01-EMB Date de création : 12/02/18 Version: a

Dosage des éléments majeurs

Dosage de 33 éléments par spectroscopie d'émission atomique avec plasma couplé par induction selon la norme ISO 11885, AOUT 2007

Opérateur :
Date d'exécution:
Signature:

Date de réception : début du cycle
Nature de l'échantillon:

Ech	Elément	% MS	V_0	Prise d'essai	Dilution	Lecture échant.	Lecture Blanc	[C]
			ml	g		mg/l	mg/l	(g/KgMS)
Prédéchets	Calcium	94	50	0,5058	10	68,34	0,0052	71,86
	Magnésium	94	50	0,5058	10	2,63	0	2,77
	Sodium	94	50	0,5058	10	1,73	0	1,82
	Potassium	94	50	0,5058	10	11,23	0,145	11,66
	Phosphore	94	50	0,5058	10	2,2	0,025	2,29
					MR		Intervalle	
MR Ca	100mg/l				97,15	95 - 105		
MR Mg	100mg/l				96,38	95 - 105		
MR Na	100mg/l				93,77	95 - 105		
MR K	100mg/l				98,17	95 - 105		
MR P	100mg/l				98,25	95 - 105		

Observation:

La formule :

$$C\ (g/kgMS) = \frac{([\text{Lecture Ech} - \text{Lecture Blanc}] * V0 * \text{dilution})/1000}{M * \%MS/100}$$

%MS pourcentage de la matière sèche
V_0: Volume en millilitres de l'echantillon à doser
Lecture Echantillon: c'est la concentration obtenue du l'echantillon
Lecture Blanc: c'est la concentration obtenue du blanc

Validation n°:
Unité:
Nom et prénom:
Date de validation:
Signature:

Remise de la fiche suiveuse à la réception
Nom et prénom:
Date:
Signature:

Annex II.4. Results of the dosage of major elements in kitchen organic waste composting (end of the cycle) carried out in Tunisia

DIRECTION DU LABORATOIRE	**Fiche suiveuse**	Codification : EC-V.9/01-EMB Date de création : 12/02/18 Version: a

Dosage des éléments majeurs

Dosage de 33 éléments par spectroscopie d'émission atomique avec plasma couplé par induction selon la norme ISO 11885, AOUT 2007

Opérateur :
Date d'exécution:
Signature:

Date de réception : Fin du cycle
Nature de l'échantillon:

Ech	Elément	% MS	V_0	Prise d'essai	Dilution	Lecture échant.	Lecture Blanc	[C]
			ml	g		mg/l	mg/l	(g/KgMS)
Bio déchet	Calcium	92	50	0,5003	10	96,52	0	104,85
	Magnésium	92	50	0,5003	10	5,759	0,514	5,70
	Sodium	92	50	0,5003	10	2,69	0	2,92
	Potassium	92	50	0,5003	10	15,76	0,346	16,74
	Phosphore	92	50	0,5003	10	2,98	0,242	2,97

					MR		Intervalle	
MR Ca	100mg/l				98,12	95 - 105		
MR Mg	100mg/l				95,36	95 - 105		
MR Na	100mg/l				93,67	95 - 105		
MR K	100mg/l				99,16	95 - 105		
MR P	100mg/l				96,08	95 - 105		

Observation:

La formule :

$$C\ (g/kgMS) = \frac{([\text{Lecture Ech} - \text{Lecture Blanc}] * V0 * \text{dilution})/1000}{M * \%MS/100}$$

%MS pourcentage de la matière sèche
V_0: Volume en millilitres de l'echantillon à doser
Lecture Echantillon: c'est la concentration obtenue du l'echantillon
Lecture Blanc: c'est la concentration obtenue du blanc

Validation n°:
Unité:
Nom et prénom:
Date de validation:
Signature:

Remise de la fiche suiveuse à la réception
Nom et prénom:
Date:
Signature:

Annex II.5. Results of heavy metals analyses carried out for green waste composting (start of the cycle)

DIRECTION DU LABORATOIRE	Fiche suiveuse	Codification : EC-V.9/01-MLB Date de création : 12/02/18 Version: a

DOSAGE DES METAUX LOURDS

Dosage de 33 éléments par spectrométrie d'émission atomique avec plasma couplé par induction.
selon la norme ISO 11885 - Aout 2007

Opérateur :
Date d'exécution:
Signature:

Date de réception : début du cycle
Nature de l'échantillon:

Réf	Élément	P.E (g)	Coef. MS (%)	Vm (ml)	Dilution (ml)	Lecture Blanc (mg/l)	Lecture Ech (mg/l)	[C] (mg/kg) MS
DV	Al							
	Cd	0,5086	94	50	1	0,017	0,020	0,314
	Co	0,5086	94	50	1	0,0140	0,045	3,21
	Cu	0,5086	94	50	1	0	0,4306	45,03
	Fe	0,5086	94	50	1	0,028	22,72	2373
	Pb	0,5086	94	50	1	0	0,11019	11,52
	Mn	0,5086	94	50	1	0,322	1,760	150,4
	Ni	0,5086	94	50	1	0,332	0,572	25,048
	Zn	0,5086	94	50	1	0	0,818	85,51
	Cr	0,5086	94	50	1	0	0,175	18,25

Matériaux de références		Lecture	Intervalle
MR 50mg/l	Al		[95 -105]
MR 0,5mg/l	Cd	0,49	[0,475 - 0,525]
MR 5mg/l	Co	5,1	[4,75 - 5,25]
MR 5mg/l	Cu	5,0	[4,75 - 5,25]
MR 25mg/l	Fe	25,6	[24,75 - 25,25]
MR 5mg/l	Pb	5,1	[4,75 - 5,25]
MR 5mg/l	Mn	5,1	[4,75 - 5,25]
MR 5mg/l	Ni	5,1	[4,75 - 5,25]
MR 5mg/l	Zn	5,0	[4,75 - 5,25]
MR 5mg/l	Cr	5,1	[4,75 - 5,25]

Observation :

La Formule :

[C] (mg/Kg) MS = (lecture -blanc)*dilution*volume de préparation/(prise d'essai*%MS/100)

lecture de l'échantillon: mesure de la concentration dans l'échantillon après attaque
lecture du blanc :mesure de la concentration dans le blanc des réactif après attaque
Vm: volume de la préparation
P.E : la masse de la prise d'éssai

Validation n°:
Unité:
Nom et prénom:
Date de validation:
Signature:

Remise de la fiche suiveuse à la réception

Nom et prénom:
Date:
Signature:

Annex II.6. Results of heavy metals analyses carried out in Tunisia for green waste composting (end of the cycle)

DIRECTION DU LABORATOIRE	Fiche suiveuse	Codification : EC-V.9/01-MLB Date de création : 12/02/18 Version: a

DOSAGE DES METAUX LOURDS

Dosage de 33 éléments par spectrométrie d'émission atomique avec plasma couplé par induction. selon la norme ISO 11885 - Aout 2007

Opérateur :
Date d'exécution:
Signature:

Date de réception : fin du cycle
Nature de l'échantillon:

Réf	Élément	P.E (g)	Coef. MS (%)	Vm (ml)	Dilution (ml)	Lecture Blanc (mg/l)	Lecture Ech (mg/l)	[C] (mg/kg) MS
DV	Al							
	Cd	0,511	94	50	1	0	0,002	0,160
	Co	0,511	94	50	1	0,0065	0,027	2,08
	Cu	0,511	94	50	1	0,025	0,2231	20,62
	Fe	0,511	94	50	1	0,016	16,55	1721
	Pb	0,511	94	50	1	0	0,0301	3,13
	Mn	0,511	94	50	1	0,0663	0,702	66,2
	Ni	0,511	94	50	1	0,017	0,166	15,479
	Zn	0,511	94	50	1	0	0,303	31,52
	Cr	0,511	94	50	1	0,155	0,270	11,94

Matériaux de références		Lecture	Intervalle
MR 50mg/l	Al		[95 -105]
MR 0,5mg/l	Cd	0,49	[0,475 - 0,525]
MR 5mg/l	Co	5,1	[4,75 - 5,25]
MR 5mg/l	Cu	5,0	[4,75 - 5,25]
MR 25mg/l	Fe	25,6	[24,75 - 25,25]
MR 5mg/l	Pb	5,1	[4,75 - 5,25]
MR 5mg/l	Mn	5,1	[4,75 - 5,25]
MR 5mg/l	Ni	5,1	[4,75 - 5,25]
MR 5mg/l	Zn	5,0	[4,75 - 5,25]
MR 5mg/l	Cr	5,1	[4,75 - 5,25]

Observation :

La Formule :

[C] (mg/Kg) MS = (lecture -blanc)*dilution*volume de préparation/(prise d'essai*%MS/100)

lecture de l'échantillon: mesure de la concentration dans l'échantillon après attaque
lecture du blanc :mesure de la concentration dans le blanc des réactif après attaque
Vm: volume de la préparation
P.E : la masse de la prise d'éssai

Validation n°:
Unité:
Nom et prénom:
Date de validation:
Signature:

Remise de la fiche suiveuse à la réception

Nom et prénom:
Date:
Signature:

Annex II.7. Results of heavy metals analyses carried out in Tunisia for kitchen organic waste composting (start of the cycle)

DIRECTION DU LABORATOIRE	Fiche suiveuse	Codification : EC-V.9/01-MLB Date de création : 12/02/18 Version: a

DOSAGE DES METAUX LOURDS

Dosage de 33 éléments par spectrométrie d'émission atomique avec plasma couplé par induction. selon la norme ISO 11885 - Aout 2007

Opérateur :
Date d'exécution:
Signature:

Date de réception : début cycle
Nature de l'échantillon:

Réf	Élément	P.E (g)	Coef. MS (%)	Vm (ml)	Dilution (ml)	Lecture Blanc (mg/l)	Lecture Ech (mg/l)	[C] (mg/kg) MS
Bio déche	Al							
	Cd	0,5014	94	50	1	0	0,001	0,127
	Co	0,5014	94	50	1	0,0250	0,052	2,88
	Cu	0,5014	94	50	1	0	0,5419	57,49
	Fe	0,5014	94	50	1	0,349	35,13	3690
	Pb	0,5014	94	50	1	0,0622	0,12544	6,71
	Mn	0,5014	94	50	1	0	1,016	107,8
	Ni	0,5014	94	50	1	0,002	0,223	23,445
	Zn	0,5014	94	50	1	0	0,588	62,36
	Cr	0,5014	94	50	1	0,004	0,424	44,55

Matériaux de références		Lecture	Intervalle
MR 50mg/l	Al		[95 -105]
MR 0,5mg/l	Cd	0,49	[0,475 - 0,525]
MR 5mg/l	Co	5,1	[4,75 - 5,25]
MR 5mg/l	Cu	5,0	[4,75 - 5,25]
MR 25mg/l	Fe	25,6	[24,75 - 25,25]
MR 5mg/l	Pb	5,1	[4,75 - 5,25]
MR 5mg/l	Mn	5,1	[4,75 - 5,25]
MR 5mg/l	Ni	5,1	[4,75 - 5,25]
MR 5mg/l	Zn	5,0	[4,75 - 5,25]
MR 5mg/l	Cr	5,1	[4,75 - 5,25]

Observation :

La Formule :

[C] (mg/Kg) MS = (lecture -blanc)*dilution*volume de préparation/(prise d'essai*%MS/100)

lecture de l'échantillon: mesure de la concentration dans l'échantillon après attaque
lecture du blanc :mesure de la concentration dans le blanc des réactif après attaque
Vm: volume de la préparation
P.E : la masse de la prise d'éssai

Validation n°:
Unité:
Nom et prénom:
Date de validation:
Signature:

Remise de la fiche suiveuse à la réception

Nom et prénom:
Date:
Signature:

Annex II.8. Results of heavy metals analyses carried out in Tunisia for kitchen organic waste composting (end of the cycle)

DIRECTION DU LABORATOIRE	Fiche suiveuse	Codification : EC-V.9/01-MLB Date de création : 12/02/18 Version: a

DOSAGE DES METAUX LOURDS

Dosage de 33 éléments par spectrométrie d'émission atomique avec plasma couplé par induction.
selon la norme ISO 11885 - Aout 2007

Opérateur :
Date d'exécution:
Signature:

Date de réception : Fin du cycle
Nature de l'échantillon:

Réf	Élément	P.E (g)	Coef. MS (%)	Vm (ml)	Dilution (ml)	Lecture Blanc (mg/l)	Lecture Ech (mg/l)	[C] (mg/kg) MS
Bio déchet	Al							
	Cd	0,5003	92	50	1	0,0006	0,001	0,056
	Co	0,5003	92	50	1	0,0250	0,042	1,87
	Cu	0,5003	92	50	1	0	0,1641	17,83
	Fe	0,5003	92	50	1	0,011	10,43	1132
	Pb	0,5003	92	50	1	0,133	0,1515	2,01
	Mn	0,5003	92	50	1	0,009	0,517	55,2
	Ni	0,5003	92	50	1	0,037	0,137	10,820
	Zn	0,5003	92	50	1	0	0,237	25,75
	Cr	0,5003	92	50	1	0,004	0,145	15,27

Matériaux de références		Lecture	Intervalle
MR 50mg/l	Al		[95 -105]
MR 0,5mg/l	Cd	0,49	[0,475 - 0,525]
MR 5mg/l	Co	5,1	[4,75 - 5,25]
MR 5mg/l	Cu	5,0	[4,75 - 5,25]
MR 25mg/l	Fe	25,6	[24,75 - 25,25]
MR 5mg/l	Pb	5,1	[4,75 - 5,25]
MR 5mg/l	Mn	5,1	[4,75 - 5,25]
MR 5mg/l	Ni	5,1	[4,75 - 5,25]
MR 5mg/l	Zn	5,0	[4,75 - 5,25]
MR 5mg/l	Cr	5,1	[4,75 - 5,25]

Observation :

La Formule :

[C] (mg/Kg) MS = (lecture -blanc)*dilution*volume de préparation/(prise d'essai*%MS/100)

lecture de l'échantillon: mesure de la concentration dans l'échantillon après attaque
lecture du blanc :mesure de la concentration dans le blanc des réactif après attaque
Vm: volume de la préparation
P.E : la masse de la prise d'éssai

Validation n°:
Unité:
Nom et prénom:
Date de validation:
Signature:

Remise de la fiche suiveuse à la réception

Nom et prénom:
Date:
Signature:

Annex II.9. Results of physicochemical and heavy metals analysis of green waste composting carried out in Germany

Landwirtschaftliche Untersuchungs- und Forschungsanstalt der LMS Agrarberatung GmbH

LMS LUFA ROSTOCK

ENVERO GmbH
Zur Mooskuhle 3

18059 Rostock

Telefon: 0381 203070
Telefax: 0381 2030790
Mail: info@lms-lufa.de

DAkkS Deutsche Akkreditierungsstelle D-PL-14484-07-00

Grünabfälle

Prüfbericht

Labornummer: **18-11254-003** Datum: 30.10.2018
Probe-Nr.: 3
Probenbezeichnung: 257-18

Probenehmer: Auftraggeber
Probenahme:

Probenbehälter: PE-Behälter, unverpl.
Prüfzeitraum von: 16.10.2018
bis: 30.10.2018

Untersuchungsergebnisse

Parameter	Einheit	Ergebnis in FM	Ergebnis in TM	Grenze	Methode
Wassergehalt	%	58,6			DIN EN 12880-S2a
Trockenmasse	%	41,4			DIN EN 12880-S2a
Stickstoff ges. als N	%	0,93	2,25		VDLUFA II 3.5.2.7
Phosphor, ges. als P2O5	%	0,15	0,36		DIN EN ISO 11885-E22
Kalium, ges. als K2O	%	0,53			DIN EN ISO 11885-E22
Magnesium, ges. als MgO	%	0,16	0,40		DIN EN ISO 11885-E22
Blei (Pb)	mg/kg		2,89		DIN EN ISO 11885-E22
Cadmium (Cd)	mg/kg		0,03		DIN EN ISO 11885-E22
Chrom (Cr)	mg/kg		1,55		DIN EN ISO 11885-E22
Kupfer (Cu)	mg/kg		10,50		DIN EN ISO 11885-E22
Nickel (Ni)	mg/kg		1,27		DIN EN ISO 11885-E22
Quecksilber (Hg)	mg/kg		0,06		DIN EN 1483-E 12
Zink (Zn)	mg/kg		35,16		DIN EN ISO 11885-E22

n.n. = nicht nachweisbar, n.b. = nicht bestimmbar, *) = Methode validiert, aber nicht akkreditiert, **) = Untersuchung erfolgte durch Fremdlabor

Dr. Nicole Overschmidt
Anorganische Analytik

Annex II.10. Results of physicochemical and heavy metals analysis of kitchen organic waste composting carried out in Germany

Landwirtschaftliche Untersuchungs- und Forschungsanstalt der LMS Agrarberatung GmbH

LMS LUFA ROSTOCK

ENVERO GmbH
Zur Mooskuhle 3

18059 Rostock

Telefon: 0381 203070
Telefax: 0381 2030790
Mail: info@lms-lufa.de

Bioabfälle

Prüfbericht

Labornummer: **18-11254-004** Datum: 30.10.2018
Probe-Nr.: 4
Probenbezeichnung: 258-18

Probenehmer: Auftraggeber
Probenahme:

Probenbehälter: PE-Behälter, unverpl.
Prüfzeitraum von: 16.10.2018
bis: 30.10.2018

Untersuchungsergebnisse

Parameter	Einheit	Ergebnis in FM	Ergebnis in TM	Grenze	Methode
Wassergehalt	%	53,1			DIN EN 12880-S2a
Trockenmasse	%	46,9			DIN EN 12880-S2a
Stickstoff ges. als N	%	1,16	2,46		VDLUFA II 3.5.2.7
Phosphor, ges. als P2O5	%	0,26	0,55		DIN EN ISO 11885-E22
Kalium, ges. als K2O	%	0,73			DIN EN ISO 11885-E22
Magnesium, ges. als MgO	%	0,28	0,61		DIN EN ISO 11885-E22
Blei (Pb)	mg/kg		7,98		DIN EN ISO 11885-E22
Cadmium (Cd)	mg/kg		0,15		DIN EN ISO 11885-E22
Chrom (Cr)	mg/kg		3,84		DIN EN ISO 11885-E22
Kupfer (Cu)	mg/kg		14,55		DIN EN ISO 11885-E22
Nickel (Ni)	mg/kg		3,25		DIN EN ISO 11885-E22
Quecksilber (Hg)	mg/kg		0,08		DIN EN 1483-E 12
Zink (Zn)	mg/kg		53,12		DIN EN ISO 11885-E22

n.n. = nicht nachweisbar, n.b. = nicht bestimmbar, *) = Methode validiert, aber nicht akkreditiert, **) = Untersuchung erfolgte durch Fremdlabor

Dr. Nicole Overschmidt
Anorganische Analytik

Annex II.11. Tunisian Standard NT 10.44 (2013) on organic amendments

Les E.T.M .sont mesurés selon la norme EN 13650

Tableau 3-Valeurs limites en E.T.M

E.T.M	Valeurs limites en E.T.M mg/Kg MS
As	18
Cd	3
Cr	120
Hg	2
Ni	60
Pb	180
Se	12

Tableau 4-Valeurs limites en cuivre et zinc

E.T.M.	Valeurs limites en E.T.M	
	mg/Kg MS	mg/Kg MO
Cu	300	600
Zn	600	1200

Pour ces deux oligo-éléments, il ya une différenciation par rapport à la matière organique. Les produits utilisant les valeurs limites par rapport à la matière organique doivent avoir un marquage spécifique obligatoire (voir paragraphe 6.2).

Annex II.12. Tunisian Standard NT 10.44 (2013) on organic amendments

Tableau 5 — Flux limites pour les amendements organiques

E.T.M	Flux maximal sur 10 ans g/ha	Flux maximal par an g/ha
As	900	270
Cd	150	45
Cr	6 000	1 800
Cu	10 000	3 000
Hg	100	30
Ni	3 000	900
Pb	9 000	2 700
Se	600	180
Zn	30 000	6 000

Le fabricant devra s'assurer que les préconisations de dose d'utilisation de son produit ne dépassent pas les flux du Tableau 5.

5.2 Critères micro-biologiques

Les valeurs limites en agents pathogènes présents dans les amendements organiques doivent être inférieures aux valeurs limites du Tableau 6. La conformité aux valeurs du Tableau 6 est appréciée sur les analyses effectuées sur les produits commercialisables présents sur le site de production.

Tableau 6 — Valeurs limites en agents pathogènes (sur produit brut)

	Toutes cultures sauf cultures maraichères	Cultures maraichères	Méthodes d'analyse
Œufs d'helminthes viables	Absence dans 1,5 g	Absence dans 1,5 g	
Salmonella	Absence dans 1 g	Absence dans 25 g	NT 16.15
Escherichia coli	$<10^2$ /g		NT 16.55-2
Entérocoques	$<10^4$/g		NT 09.85

NOTE Il convient d'accorder le plus grand soin aux méthodes d'échantillonnage et de conservation des échantillons.

Annex II.13. Results of the compost tests carried out in Tunisia and in Germany

Parameters		Realised tests in Tunisia		Realised tests in Tunisia		Standard NT 10.44 (2013)	Realised tests in Germany		Standard ISO 11885-E22
		Initial - Compost 1	Initial - Compost 2	Final - Compost 1	Final - Compost 2		Final - Compost 1	Final - Compost 2	
pH		6.5	5.83	7.65	7.07		8.18	7.72	
COT		520	594	113	156		-	-	
Nitrogen		14.44	18.38	10.25	12		-	-	
C/N		36.01	33.56	11	13		18.30	13.75	
MO		742.78	805.21	245.38	357.56		324	322	
The major elements	Calcium (CaO)	52.43	71.86	74.80	104.85	Absence of standards relating to mineral elements	-	-	Absence of standards relating to mineral elements
	Magnesium (Mg)	2.59	2.77	4.75	5.70		1.6	2.8	
	Potassium (K2O)	9.72	11.66	11.78	16.74		5.3	7.3	
	Phosphorus (P2	2.15	2.29	2.85	2.97		1.5	2.6	
	Sodium (Na)	1.57	1.82	2.84	2.92		-	-	
Heavy metals	Cadmium (Cd)	0,31	0,12	0,16	0,05	3	0.03	0.15	3
	Cobalt (Co)	3,21	2,88	2,08	1,87	-	-	-	-
	Copper (Cu)	45.03	57,49	20,62	17.83	300	10.50	14.55	400
	Iron (Fe)	2373	3690	1721	1132	-	-	-	-
	Lead (Pb)	11,52	6,71	3,13	2,01	180	2.89	7.98	300
	Manganese (Mn)	150.43	107.8	66.2	55.23	-	-	-	-
	Nickel (Ni)	25,04	23,44	15.47	10,82	60	1.27	3.25	50
	Zinc (Zn)	85,51	62,36	31,52	25,75	600	35.16	53.12	1250
	Chromium (Cr)	18.25	44.55	11,94	15.27	120	1.55	3.84	100
Trace metals	Se	<0.05	<0.05	<0.05	<0.05	12	-	-	-
	Sb	0.765	<0.05	<0.05	<0.05	-	-	-	-
	As	<0.05	0.1051	<0.05	0.00520	18	-	-	-
	Sn	<0.05	<0.05	<0.05	<0.05	-	-	-	-
	Mercury (Hg)	0.646	0.570	0.0315	0.0646	2	0.06	0.08	2.0
Total coliforms		$2.1.10^4$	$4.6.10^4$	$4.3.10^3$	$2.3.10^3$	$<10^4$	-		
Faecal coliforms		$2.1.10^5$	$2.8.10^5$	$2.3.10^3$	$9.3.10^3$				
Streptococci		$9.3.10^3$	$2.1.10^3$	$7.4.10^2$	$1.5.10^3$				
Escherichia coli		$9.3.10^4$	$0.21.10^3$	3.10^1	-	$<10^2$			

CURRICULUM VITAE

Wassim CHAABANE

ENVIRONMENT AND WASTE MANAGEMENT / MARINE LITTER

TRAINER - STRATEGIC PLANNING (RESULTS BASED MANAGEMENT)
Member - International Solid Waste Association (ISWA)

Current address: Bremer str 25, Ostercappeln 49179, Germany
Tel: +4915234519327 / +216 22991969
Email: chaabane.wassim@gmail.com
Birth date: 31.03.1988

Diploma

Institutions (Start date - End Date)	Obtained and Planned Diplomas
Rostock University (Germany) - 10/2016 to 04/2020	Dr.-Eng. Environment, Waste and Resources Management – Sustainable tourism and WM
Lund University (Sweden), 11/ 2019 to 12/2019 (Certified Online course)	Circular Economy - Sustainable Materials Management
Higher Institute of Biotechnology of Sfax ; 10/2010 to 07/2012	Master of Sciences and Environmental Technologies
Higher Institute of Biotechnology of Sfax ; 10/2007 to 06/2010	Bachelor Biotechnology : Control and Exploitation of Microorganisms
Hadi Soussi School, Sfax, 2007	Baccalaureate Experimental Sciences

Languages: (1 level excellent, 5- rudimentary level)

Languages	Read	Spoken	Written
Arabic	Mother tongue		
French	1	1	1
English	1	1	1
German	2	3	3

Years of experience and Key qualifications: More than 9 years (GIZ, Konrad Adenauer Stiftung, Heinrich Böll Stiftung, World Research Institute, European Union, Private sector, Universities, NGOs)

- Environment and Waste Management projects coordination and development
- Trainer – Environment and sustainable development
- Extended Producer Responsibility / Circular Economy / Marine litter / Plastic prevention
- Design and project proposal writing
- Communication in the fields of environment and sustainable development
- Animation of working groups on sustainable development and waste management
- Trainer: strategic planning (Results Based Management approach)
- Waste management projects conceptualisation for municipalities and NGOs

Main Professional References:

Date	Place	Beneficiary	Position	Description
June 2020 to December 2020	Germany, Tunisia	The World Bank	International Expert	Diagnostic of the current situation of solid waste management situation in Tunisia, in preparation of the development of the PCGD – Municipal Waste Management Plan guide for municipalities in Tunisia
April, 2020 (on going)	Jordan	cyclos GmbH	Consultant	Implementation of Extended Producer Responsibility (EPR) in Jordan
November, 2017 – (on going)	Tunisia	cyclos GmbH	Consultant	Extended Producer Responsibility (EPR) - The project is supported by the GIZ for two and a half years. The project objective is to diagnose the current ECO-Lef system and to develop new options for its optimisation. In cooperation with ANGED and all relevant parties, a framework law is being developed.
February, 2020	Tunisia	EU Med Dialogue for Rights and Equality	Facilitator	Support the coordination and carrying out of the capacity building bootcamp on ecological challenges
January, 2020 (on going)	Tunisia/ Germany	Frauenhofer Umsicht, Municipalities (Douar Hicher, Siliana, Tabarka)	Consultant	Data collection and diagnostic of SWM in three municipalities (Douar Hicher, Siliana, Tabarka), with the aim of developing waste management infrastructure (recycling centres, composting plants, etc).
October, 2019	Tunisia	WWF	Trainer	Strategic Planning – "Results Based Management" approach for 30 associations from Tunisia. Theme: Climate change
September, 2019	Tunisia	Heinrich Böll Stiftung/Ministry of Local Affaires and Environment	Consultant	- Redaction of two articles related to marine litter and plastic pollution in Tunisian Islands and the current waste recovery system in Tunisia - Development and review of the term of references for the national strategy of waste management in Tunisia/ Participation in the national waste management strategy
August, 2019	Kerkennah, Tunisia	GIZ / Municipality of Kerkennah	Consultant	Technical support to the municipality of Kerkennah/ Solid waste management
April, 2019 – May, 2019	Greifswald, Germany	OVVD, Rostock University	Technical Assistant	Sorting analyses of the solid waste generated in Greifswald, Germany. The study is considered as a basis for decision makers.
March 2019 – September 2019	Hammamet Tunisia	Municipality of Hammamet	Project Supervisor	Waste characterisation from hotels and from households and green waste composting – Test period
November, 2018	Bizerte, Tunisia	WWF	Trainer	Enabling Libyan NGOs to shape the future of the new Libyan Democracy: "Libyan Environmental NGOs: Solid Waste Management".

August – September, 2018	Tunis, Tunisia	Heinrich Böll Stiftung	Consultant	Elaboration of a study on marine pollution by plastics and micro-plastics in Tunisia
September, 2018	Hammamet, Tunisia	WWF	Trainer	Enabling Libyan NGOs to shape the future of the new Libyan Democracy: "Libyan Environmental NGOs: Corporate communication for sustainability".
January, 2018- Now	USA/Germany	WRI (World Research Institute)	Researcher	UN Environment, Plastics Study: Study on plastics and documentation of the state of laws and regulations that regulate three types of plastics (plastic bags, single use plastics and cosmetics) in different countries: Saudi Arabia, Tunisia, Morocco, Afghanistan, Oman, Syria and Kuwait.
September, 2018	Germany	BN Umwelt	Technical Assistant	Support for the project, "Development of an adapted 'Mechanical Biological Treatment' Plant in the Tunisian context".
January, 2018 – May, 2018	Tunisia	GIZ	Project Leader	**Diagnostic of the current solid waste management system in the tourism sector in Tunisia**. Proposal of a new sustainable concept for the tourist destinations (waste reduction at source, waste sorting, etc.)
January, 2016 to June, 2018	Djerba, Tunisia	Ministry of Higher Education and Research (Tunisia), BMBF (Germany)	Researcher	**SUREMAD Project**: Sustainable management of resources in the tourism sector: The example of Djerba.
December, 2017	Tunis, Tunisia	Taysir Microfinance, Tunis Municipality	Consultant	**Evaluation of the impact of the installation of the sorting cages in the municipality of Tunis:** The evaluation concerns the economic, social and environmental impacts.
September, 2015 to March, 2016	Tunis, Tunisia	GIZ	National Expert	**Unit Mechanism Management** for the attenuation of greenhouse gases from cement industries
February, 2015 to July, 2015	Tunis, Tunisia	SWEEP-Net /GIZ	Technical Coordinator	**Selective Waste Collection of Offices and Institutions:** A pilot project aimed at collecting office waste separately in order to recycle it (mainly paper, cardboard and plastic). The main actors of the project: SWEEP-Net Project (Initiator), GIZ projects, ANGED, Ministry of Environment and Sustainable Development, African Recycling Company.
April, 2015	Tunis, Tunisia	SWEEP-Net /GIZ	Technical Coordinator	**SWEEP-Net fifth regional forum:** For the fifth consecutive year, SWEEP-Net held its regional forum on integrated solid waste management.
February, 2015	Djerba, Tunisia	SWEEP-Net /GIZ	Technical Coordinator	**Cost of Environmental Degradation (COED) due to Solid Waste Management Practices – SWM Crisis in Djerba Island - Tunisia**
November, 2014	Genova, Italy	MED3R - European Union	Technical Support (SWEEP-Net)	**MED3R - Euro-Mediterranean Platform, Recycle - Reduce – Reemploy**

January, 2014 to April, 2014	Tunis, Tunisia	SWEEP-Net /GIZ	Technical Coordinator	**Participation in the realisation of the 'Cost of Environmental Degradation due to Solid Waste Management' report: Tunis (Tunisia), Beirut (Lebanon) and Rabat (Morocco).**
January, 2014 to December, 2014	Tunis, Tunisia	SWEEP-Net /GIZ Municipalities of La Marsa, Sidi Bousaid and Carthage	Technical Coordinator	**Communal Waste Management Plan (Marsa, Sidi Bousaid, Carthage) Phase I/Phase II**: The PCGD, the Communal Waste Management Plan, is a programme initiated by ANGED (the National Waste Management Agency). It is financed by the German Development Agency, GIZ, and has been running for several years.
April, 2015	Bremen, Koln, Wuppertal, Germany	SWEEP-Net /GIZ	Head of Delegation	**Study visit to Germany/E-Learning Programme on Solid Waste Management:** This initiative is based on hybrid training including a study visit in Germany and a second part of the training to be conducted through a platform of e-learning: - Supervising the training technical manuals carried out by the experts.
April, 2014	Tunis, Tunisia	SWEEP-Net /GIZ	Technical Coordinator	**Waste Management and Informal Sector Involvement in Tunisia:** SWEEP-Net/GIZ is supporting solid waste system modernisation by working with two municipalities in Tunis - Ettadhamen- Mnihla and La Marsa - to develop a vision and a plan for the integration of informal recyclers into the plans for improving the solid waste management system.
May, 2014	Amman, Jordan	SWEEP-Net /GIZ	Technical Coordinator	**SWEEP-Net's 4th Regional Forum in Amman/Jordan (May 2014): 'MOVING UPSTREAM: Waste and Resource Management with Social and Economic Benefits'.** Reflections on the circular economy, transforming waste management into resource management, informal sector involvement in the solid waste sector, waste as alternative fuels and source of energy, regional reporting on SWM and benchmarking system, extending policy to waste prevention/waste governance, private sector involvement on a municipal level, marine litter, producer and consumer responsibility, cost of environmental degradation, CCAC, and reducing methane and black carbon through sustainable municipal solid waste practices.
January, 2014 to August, 2015	Sfax, Tunisia	SWEEP-Net /GIZ-Municipality of Sfax	Technical Coordinator	**Public Private Partnership - Underground Waste Containers Installation in Sfax/Tunisia (Clinics, Hospitals, Restaurants, etc.):** An agreement was reached between SWEEP-Net and the municipality of Sfax to install 55 underground containers to improve waste management situation in the city.
March, 2013 to June, 2014	Sfax, Tunisia	MedCities, Air Métropolitaine de Barcelone, European Union, Municipality of Sfax	Platform Manager	**Mediterranean Network for the Promotion of Sustainable Urban Development Strategies (UDS) and three new UDS – European Union:** USUDS is an initiative of MedCities, a network of Mediterranean cities created in 1991. USUDS gathers Mediterranean cities interested in building and developing strategies for urban sustainable development.

Scientific publications/published papers and reports

§ Chaabane,W. (2020), Gestion des déchets plastiques en Tunisie: Vers une responsabilité partagée, Atlas du Plastique, Heinrich Böll Stiftung, 42-43, Écologie & Gouvernance des Ressources Naturelles.
§ Chaabane,W. (2020), Les îles tunisiennes étouffent sous le plastique, Atlas du Plastique, Heinrich Böll Stiftung, 32-33, Écologie & Gouvernance des Ressources Naturelles.
§ Chaabane,W. (2020), Solid Waste Management in Tourism in Tunisia: Diagnostic and Improvement Approaches, Thesis, Rostock University.
§ Chaabane, W.; Nassour, A.; Bartnik, S.; Bünemann, A and Nelles. M (2019). Shifting towards sustainable tourism: Organisational and financial solutions for solid waste management in tourism in Tunisia. Sustainability 2019, 11, 3591.
§ Chaabane, W.; Selmi, M.; Safwat H.; Nour C.; Abdallah, N and Michael, N (2019). Monitoring of composting process parameters from kitchen waste and green waste generated in tourism destinations: a case study of Tunisia, 13. Rostocker Bioenergieforums. Juni 2019 an der Universität Rostock. ISBN 978-3-86009-487-7. Vol. 87, pp: 325-335.
§ Chaabane, W.; Nassour, A and Nelles, M (2018). Solid waste management key indicator development for hotels: a Tunisian case study analysis. Recycling, 3, 56.
§ Chaabane, W.; Nassour, A.; Nelles, M and Salmi, M. (2019) Solid waste management in tourist destinations in Tunisia: reality and perspectives. Deutsche Gesellschaft für Abfallwirtschaft e.V. (DGAW). DGAW-Wissenschaftskongress „Abfall- und Ressourcenwirtschaft“. März 2019 an der OTH in Amberg/Weiden. ISBN 978-3-903187-48-1. Vol. 9, Pp: 171-176.
§ Chaabane, W.; Baccar. A (2019). Debris marin, plastique et micro-plastique sur les côtes tunisienne, Heinrich Boll Stiftung (Tunis). [In French].
§ Nassour, A.; Hemidat, S. Chaabane, W and Nelles, M. (2018). Current developments in waste management in the Arab world. Müll und Abfall, Fachzeitschrift für Abfall- und Ressourcewirtschaft, ISBN 978-3-503-17664-9. Vol. 4, pp: 160-166. [In German].