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Chapter

Towards the Recycling of Bio-Waste: The Case of Pontevedra, Spain (REVITALIZA)

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Abstract

Waste management is one of the main environmental problems that municipalities have to address. The fulfilment of the recycling objectives imposed by the European Community requires the segregation and treatment of the municipal bio-waste. Pontevedra Provincial Council started in 2015 an innovative plan, called REVITALIZA, for the recycling of bio-waste through the promotion of composting in municipalities. REVITALIZA, which is developed in different phases, advocates the implementation of local composting (home and community composting) and small composting facilities, so that the generation of waste and the economic and environmental costs of its collection and transport are reduced. The plan is a pioneer in the training of technical personnel in the area of bio-waste management. Currently, 36 municipalities are participating in REVITALIZA in different phases of the plan, committed to locally managing bio-waste.

Keywords: composting, bio-waste, recycling, decentralized waste management, community composting centre, master composter

1. Introduction

Municipal waste generation in the European Union (EU) is estimated around 246,515 thousand tonnes in 2016, so the amount generated per person amounted to 483 kg [1]. Municipal waste represents only around 10% of total waste generated in the EU. However, its heterogeneous composition and universal distribution as well as the economic cost that the collection and treatment of this waste involve—especially for small and dispersed local authorities—cause a complex management and a high risk of environmental and socioeconomic impact in response to inadequate handling. Municipal waste management varies significantly across the EU member states. While Germany sent to landfill 2% and recycled and composted 66% of total municipal waste, countries such as Greece, Cyprus or Malta sent to landfill over 80% of municipal waste [1]. Municipal waste prevention and reuse, through responsible consumption, separation into the different elements found in waste streams and an appropriate management of these fractions, bring social and environmental benefits (priority hierarchy for solid waste management, [2]). The municipal waste management practices affect citizens: economic (waste collection fee) and environmental impacts (emissions and indirect system effects), but

also more diffuse effects such as the physical connection with waste management through the design of the collection system and the psychological effect of the localization of waste management facilities [3]. The management of municipal waste must improve in order to move towards more sustainable systems, in accordance with the criteria of circular economy and with the involvement of citizens. European legislation and policy establish the necessary actions in order to ensure proper application of the waste hierarchy, turning waste into resources as a priority. The Waste Framework Directive sets a target of 50% of municipal waste to be prepared for reuse or recycled by 2020 in EU member states, progressively increasing this target up to 65% by weight by the year 2035 [2, 4]. Bio-waste, as part of municipal waste, is defined as biodegradable garden and park waste; food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants. The content of bio-waste in municipal waste differs considerably between EU member states (20–80%); the implementation of separate collection and the treatment system of this biodegradable fraction also vary widely [5]. In general, by 31 December 2023, bio-waste must be either separated and recycled at source, or collected separately and not mixed with other types of waste [4]. Bio-waste is a valuable organic resource with a high potential for recycling and reuse, producing valuable products such as fertilizers or biogas. However, inefficient and neglected management can generate bio-waste breakdown and pollution, reducing the efficiency of subsequent treatment operations and generating human health and environmental impacts.

Around 20,585 thousand tonnes of municipal waste were generated in Spain in 2016, 57% sent to landfill and 30% recycled and composted, values far from the objectives established by the EU. Assuming that about 40% of municipal waste is bio-waste, this means that 8234 thousand tonnes of bio-waste were generated in Spain. In general, bio-waste is not source-separated and it is estimated that only 8% of this biodegradable waste is collected separately [6]. According to the 'Proximity Principle' of the EU, waste should be treated and disposed off close to where it was produced. Public administrations responsible for waste management should promote the local treatment of bio-waste. Food waste degrades quickly, generating leachates and odours, so reducing the waste treatment time prevents undesirable situations. Composting is an economically accessible and appropriate option, since it can be carried out at different scales with a simple and low-cost technology, which allows its location in places close to bio-waste producer. Composting is a controlled bio-oxidative process, which develops on heterogeneous organic substrates in solid state, due to the sequential activity of a great diversity of microorganisms. The process enables organic waste to be transformed into biologically stable materials called compost. The compost can be used as an amendment and/or soil fertilizer and as a substrate for plant growth, closing nutrient cycles. Due to the composition of municipal waste, source segregation of bio-waste at household level must ensure a material without other waste streams. Only the biodegradable fraction free from impurities can be used as input for composting to obtain a high-quality compost that is environmentally safe for use. Good waste segregation requires active participation of the citizens.

Actions that promote bio-waste segregation and the use of the most appropriate treatment options to obtain quality products, such as compost, must be prioritized in order to comply with current regulations and respect the environment. In this way, the implementation of new municipal models of organic waste management through composting is growing exponentially [7]. The decentralized management of biodegradable waste consists in on-site treatment (home composting, community composting and small composting facilities), while centralized management involves collection from the site of producer's deposit and transport to a central treatment facility.

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In this sense, to change the centralized model of waste management in the province of Pontevedra, a composting plan is developed. This plan is based on the promotion and implementation of bio-waste composting with the criteria of population distribution and the prioritization of the principle of proximity in waste management. It includes an important effort in the awareness and training of citizens, as well as the training of professionals and experts in waste management in general, and the composting process in particular. The municipalities of the province of Pontevedra drive their efforts towards a decentralized model of bio-waste management.

2. The province of Pontevedra

Spain is made up of 50 provinces, one of which is Pontevedra. The province of Pontevedra lies in the northwest of the Iberian Peninsula. It is bordered to the south by Portugal and to the west by Atlantic Ocean (**Figure 1**).

The province has an area of 4495 km^2. It has a population of 942,731 inhabitants in 61 municipalities. With a population density of 209 inhabitants km^{-2}, Pontevedra is considered as an intermediate region according to the rurality indexes [8]. However, the population is more intensively concentrated in the metropolitan areas of the capital, Pontevedra, and the city of Vigo and along the coastal area. The eastern area of the province is a rural zone, with less densely populated municipalities, some of them with densities less than 50 inhabitants km^{-2}. **Table 1** shows the analysis of population dispersion data in the province. The population nuclei are distinguished according to the number of inhabitants in the settlement. A population nucleus, in its broadest sense, is considered to be a set of at least 10 buildings



Figure 1.
Map of Spain showing its position in Europe; the study area of Pontevedra is marked with orange colour.

	Population nuclei				
	Scattered	**<100**	**100–1000**	**>1000**	**Total**
No. of inhabitants	209,918	69,175	197,732	484,179	961,004
No. of nuclei	17,493	1462	782	67	19,804

Table 1.
Dispersion data of the population of Pontevedra according to the size of the population nuclei. Source: prepared from the data of the Spanish Statistical Office [9].

that are made up of streets, squares and other urban roads; otherwise, the population is understood as disseminated. Around 30% of the population lives in small nuclei or scattered.

The dispersion of the population along with a complicated orography and a high rainfall involve a significant cost overrun in the public services, in general, and the municipal waste management in particular. In the waste management model of the province of Pontevedra, different waste streams are collected and managed separately: paper and cardboard, glass packaging and light packaging. Bio-waste is not source-segregated and it is collected in the mixed fraction, that is, all unsorted waste: bio-waste, sanitary textiles, ceramic waste, household cleaning waste, etc. The collection of these fractions takes place mainly in containers on public roads. Mixed fraction is managed in a centralized way in an incineration plant located at an average of 120 km from the municipalities of the province [7].

The services of collection, transport and treatment of the waste generated in the household, and similar sources such as commerce, offices and services, correspond to the municipalities. Each municipality decides how to provide and finance these services. These services suppose a high economic cost for the small and medium municipalities due to the difficulty in reaching a critical mass that optimizes the resources (containers, vehicles, staff, etc.) and the gap between the real cost of the services and the taxes applied to the citizens. Municipal waste generation in the province of Pontevedra accounted for 348,326 tonnes in 2017, but only 9.04% corresponded to separate waste collection, which led the municipalities far from the recycling objectives imposed by the EU.

The Provincial Council of Pontevedra is a supra-municipal authority, which provides direct services to citizens and technical, economic and technological support to the municipalities of the province of Pontevedra. The Provincial Council of Pontevedra has been promoting the composting plan called REVITALIZA since 2015.

3. Composting plan: 'REVITALIZA'

REVITALIZA establishes a new municipal waste management model focused on the segregation and treatment of the organic fraction as close as possible to its point of generation. It includes three fundamental bases or lines of action depending on the population distribution of the province and the particularities of each housing: individual or home composting, community composting and small composting facilities. The first two lines are considered as local composting, that is, composting near the area where the waste producers live. Small composting facilities should be located in the municipality or in a municipality near the places where the bio-waste is produced, and the waste will require collection and transport. **Table 2** presents a study of the theoretical requirements calculated for each one of the bio-waste treatment lines according to the population distribution of the province (**Table 1**). This study identifies what part of the bio-waste could be treated by local composting (home and community composting), while everything that could not be treated

	Population nuclei				Total	Population served (%)
	Scattered	<100	100–1000	>1000		
No. of home composters	51,980	16,794	11,796	6368	86,937	36.6
No. of CCCs	—	—	1230	1682	2912	36.7
No. of composting facilities	—	—	—	6	6	26.7

CCC: community composting centre.
Calculated following the assumptions: community composting centre of six units and small composting facilities of 3000 tonnes year^{-1} except one facility of 25,000 tonnes year^{-1} that would provide service to the city of Vigo.

Table 2.
Theoretical requirements of equipment and/or facilities for the implementation of the three lines of action (home composting, community composting and small composting facilities) of REVITALIZA based on population distribution data of the province of Pontevedra.

from a technical point of view through this priority path would be diverted to industrial composting at small and medium scale called small composting facilities.

As mentioned in the previous section, the population distribution of the province increases the cost of treatment of the waste, as there are small-sized nuclei and scattered population in dispersed areas. Based on the data in the table, most of the population of the province of Pontevedra can be served by local composting; the small facilities are restricted, especially for urban centres. Home composting is considered an interesting alternative to central composting, especially in areas with low population density [10]. According to REVITALIZA, the municipalities with scattered population would advance towards the sustainable management of the resources by means of local or in situ treatment of the bio-waste, so that municipalities would reduce the costs and environmental impacts of the collection and management of the mixed fraction of the municipal waste. REVITALIZA promotes the following actions:

- Establish a management model that allows to replicate and adapt it in the different municipalities of the province.
- Prioritize the treatment of the organic fraction near the point of generation and, therefore, reduce the collection and transport costs assumed by municipalities every day.
- Encourage the participation of citizens in waste management.
- Train personnel qualified in waste management, in general, and in the composting process, in particular.
- Obtain compost for use as a soil amendment and close the cycle of organic matter.

Initiatives to improve waste management services and the overall sustainability environmental policy chosen by local authorities require participation of all involved stakeholders (citizens, NGOs, state authorities, etc.). In order to be successful, all actions have to be credible, transparent, socially sustainable and, as far as possible, convenient and practical to participants [11]. Thus, consciousness-raising and training capacity for citizens are fundamental for the success of the composting plan. Therefore, experts on municipal waste management and composting process are required. The Provincial Council of Pontevedra has organized selection processes and

specialized courses for the selection and training of staff called master composter. The courses had counted on the participation of expert teachers with recognized experience in the sector, both state and international. Master composters have as functions advising local governments on the composting plan and carrying out the actions, following the particularities of each municipality, for the implementation of REVITALIZA. In addition to the master composters, REVITALIZA has external collaboration from specialized associations: NGOs Amigos da Terra and ADEGA. These groups advise neighbours and control the operation of home composters. Likewise, personnel of the municipalities adhering to the plan will be trained so that they can take responsibility for the composting work in successive years. The Provincial Council of Pontevedra also carries out training actions addressed to the educational community, both teachers and students, through an agreement with the Center of University Extension and Environmental Outreach of Galicia, Spain (CEIDA).

3.1 Home composting

In accordance with the priority of minimizing the collection and transport of organic matter, the first level of REVITALIZA is local composting and, within it, individual or home composting.

The Provincial Council of Pontevedra transfers composters with capacity of 300 L to the houses with a plot of land (garden and orchard) (**Figure 2**). In this way, self-management of the bio-waste generated by the family nucleus can be carried out on site. In home composting, the participants segregate the bio-waste and deposit it in the composter, they are responsible for the composting process and they benefit from the obtained compost. Organic materials used for compost should include a mixture of food and kitchen waste and green organic material such as grass clippings, pruning remains, leaf litter, etc. Bulking agent is a carbon-based material such as chip or shredded pruning waste that creates necessary aeration structure for the composting process. The methodology used in home composters consists of alternating layers of food and kitchen waste with bulking agent that can be obtained in the garden of the participants themselves. REVITALIZA contemplates either the provision of bulking agent or the loan of crushers to process the garden waste from participants who require it.

The neighbours receive training and guidance from the associations that assist the Provincial Council. These associations carry out initial training and follow-up of the process through visits to each home composter. In the first year, at least three visits are made to check the development of the process: taking measurements of temperature, moisture control, filling level, incidents, etc. In addition, follow-up actions through telephone calls, emails, etc. are included.

3.2 Community composting

Community composting is a fundamental basis and strategic priority of REVITALIZA. Following the criterion of bio-waste management in areas close to the point of generation, composting at a community level consists in managing the bio-waste from local residents and/or activities within the same neighbourhood or community. To this end, community-composting centres (CCCs) are set up, either at neighbourhood communities or at small specific producers such as food stores, markets, bars, restaurants, hotels, etc. Community composting is considered an intermediate technique between home composting and composting in small-scale composting facility. In that sense, CCC that accepts more than 30 tonnes year^{-1} will be subject to specific legislation that includes, mainly, installations and environmental permit. A CCC is made up of modular units of 1 m^3 that serve around 20 inhabitants each. The minimum and maximum number of modular units per CCC



Figure 2.
(A) Home composter with an aerator on the lid, (B) material in composting process (C) bio-waste feeding to the composter and temperature measurement.

is 3 and 10 (**Figure 3**). The area of influence of a neighbourhood CCC is located at a maximum distance of 150 m from the homes it serves. In [12], it is observed that the larger is the distance of waste containers from the houses, the larger is the probability of waste dumping in other places. If the CCC is too far away, the probability that the neighbours deposit their waste in the container of the mixed fraction is greater. In the case of small producers' CCCs, they can be located in the producer's own facilities or in their proximity and must not exceed 30 tonnes year^{-1} of bio-waste.

Master composters evaluate the potential locations of the CCCs in the municipalities and the possible neighbourhood communities or small producers that would contribute bio-waste to the centres. The treatment capacity, the surface requirements and the material resources can be dimensioned according to the data collected by the master composters. An installation protocol has been developed for the placement of the CCC, in which the following criteria must be fulfilled:

- The land must be either municipal public property or expressly authorized by the owner.
- The land should preferably be natural and even with a maximum slope of 3%.
- The ground should be excavated about 20 cm deep for the installation of the base.
- The base consists of a lower layer of coarse gravel, a layer of fine gravel and the concrete pieces that make up the platform on which the modular units are seated and assembled.
- CCC must have a water feed for irrigation.

As an essential part of an appropriate composting process, food and kitchen waste must be mixed with bulking agent (crushed vegetable waste). This material is supplied by the municipality and comes from gardening activities, which involve pruning, cutting and removing vegetation of gardens, parks and other public spaces. The Provincial Council places at municipalities' disposal the crushing service, in case of lack of shredder equipment, so that they can prepare the remains of gardening to an optimum granulometric size for the community composting process [7]. Crates or bags with bulking agent are arranged in the CCC for use by the participants and master composters (**Figure 3**).

Participants of community composting receive initial training for the correct segregation and deposition of the bio-waste, as well as, information on the development of the composting process. The master composters continue their educational work in CCC on a day-to-day basis where they talk with the participants or interested parties and resolve their doubts and questions.

3.2.1 Composting process in CCC

The CCC working protocol is based on the complete development of the process in three modular units of composting: the first unit corresponds to the contribution or feeding module in which citizens deposit the bio-waste; while the second and third units are used to carry out the transfers (**Figure 4**). These transfers homogenize the material and, therefore, increase the efficiency of the process, which allows the first unit to be left empty for new contributions by the participants. Depending on the number of participants or the volume of bio-waste to be assumed, the number of modular units required in each CCC is set up. In this way, three stages are distinguished from the operational and process point of view in community composting.

3.2.1.1 Stage 1: bio-waste input

The neighbours deposit the bio-waste only in the modular units of feeding and immediately cover it with an equal volume of bulking agent. The master composters mix the materials so that the process begins. An intensive degradation phase takes place with a high oxygen demand, which is necessary for metabolic functions of the microorganisms. Large amounts of carbon dioxide and water vapour are released in this stage. The rise in temperature indicates that compost is developing properly.

3.2.1.2 Stage 2: homogenization

When the bio-waste input module is full, approximately in 4 weeks, the master composters move the material to the second module. The modular units are assembled together but have slide-out panels on all sides. This allows easy access on all sides and



Figure 3.
(A) Community composting centre with six modular units and bulking agent bags and (B) details of the modules during the composting process.



Figure 4.
(A) Bio-waste feeding in the first modular unit, (B) transfer of the material from the first module to the second to continue the composting process, (C) compost screening and (D) details of the physical aspect of the compost.

the movement of the material from one unit to another. Turning the material to the second module allows a more intense homogenization by mixing the most recent bio-waste inputs with degraded materials of the bottom. At this stage, the material might be too dry and the degradation process can stall; so, moisture control is important.

3.2.1.3 Stage 3: maturation

The material of the second unit is turned towards the third unit where the compost maturation takes place. The temperature drops progressively and more complex compounds are formed. The finished material has lost its original appearance. Compost is a soil-like material, dark with a pleasant earthy smell. Master composters sift the compost to facilitate its use as a fertilizer product or organic amendment. The compost can be distributed to citizens who have participated or can be employed by the municipal staff in the gardens and public areas.

As far as possible, the installation of urban or community gardens associated with CCC is promoted, so that the produced compost goes to the garden itself. The neighbours or small producers, instead of taking the compost produced for private use, would distribute the products of the garden. In [13], it has been proposed that the shift of municipal waste management systems from landfill disposal to resource recovery requires, among other aspects, sufficient urban gardens to divert the compost produced.

Throughout the process, master composters carry out the monitoring and control of composting and its key parameters (taking of temperature, filling level measurement, correction of incidents, etc.) and the necessary physical work required by the process (bulking agent addition, mixing, rewetting, turning, screening, etc.)

3.3 Small composting facility

The small composting facilities will manage bio-waste that cannot be treated through the other lines of action due to technical or operational causes. As has been described, local composting, both home and community composting, presents requirements for its implementation. In the case of high population densities

distributed in buildings of various heights, local composting cannot assume all bio-waste generated. Therefore, it is necessary to implement a collection and transport service and bio-waste treatment in composting facilities. Following the principle of proximity, these facilities should be located close to the waste-production centres, so that the bio-waste transport is minimized and the treatment in areas near the point of generation is prioritized. These facilities must be small scale, handle between 1000 and 3000 tonnes year^{-1}. These will have limited mechanization given that the input waste cannot contain non-biodegradable materials or impurities (maximum allowed 10%). Medium-scale facilities could be established in the case of the two cities with the largest population of the province: Pontevedra and Vigo.

4. Development of REVITALIZA

4.1 Implementation phases

In order to ensure the success of REVITALIZA, its progressive implementation was considered necessary, so that the different actions will demonstrate the feasibility and effectiveness of the new model.

Authors present different possibilities:

- The first phases of the plan are assumed economically by the Provincial Council of Pontevedra.
- The Provincial Council of Pontevedra covers economically the implementation of the plan in the first phases.
- The Provincial Council of Pontevedra assumes the implementation of the plan in the first phases.

4.1.1 Phase I: demonstration stage

In order to demonstrate, both to citizens and public managers, the role of community composting in the province of Pontevedra, the Provincial Council put a selective process in motion at the end of 2015. This process was aimed at municipalities that were willing to implement the management of bio-waste through community composting. The municipalities interested in this new model were selected based on the following criteria:

- Submit agreements for the contribution of bio-waste free of non-biodegradable materials by neighbours and small producers to CCC.
- Keep a supply of bulking agent for mixing with the bio-waste.
- Pick up and use the compost by the neighbours or municipal services.
- Present adequate space available for the installation of the CCC.

From this announcement, 22 municipalities were selected and 221 modular units in 46 CCCs were installed in October 2016. In turn, master composters were selected and trained to give technical support, participate actively in the physical work of community composting and solve doubts and problems that may arise during the phases of the process.

4.1.2 Phase II: adhesion and subsidies

Once the interest of the municipalities for community composting was demonstrated, the Provincial Council of Pontevedra started a new phase of REVITALIZA at the end of 2016. This phase consists in providing the necessary means for the implementation of the new management model as a global system for the treatment of bio-waste at the municipal level. With this objective, a second phase of REVITALIZA was established. Formally joining the plan was required for the municipalities to guarantee compliance with the legal obligations for the bio-waste treatment through composting. The formal adhesion of the municipalities allows them to benefit from three provincial collaboration lines: training of technical personnel, preparation of a municipal waste management plan and financial aid for composters and other resources supply.

This second phase has allowed the Provincial Council to begin the implementation of the new management model based on the local composting of bio-waste by home and community composting in five municipalities. These municipalities have decided to change the waste service betting on a decentralized model that will close the cycle of organic matter. These municipalities are Mondariz Balneario, Mondariz, As Neves, Vilaboa and O Grove. These municipal entities are small (between 1000 and 11,000 inhabitants) with a scattered population and few high-rise buildings. This new phase aims to manage 50% of the bio-waste produced in these municipalities through local composting in the next 2 years and reduce at least 25% of the organic fraction that is not reused (animal feed), donated (banks of food), composted or stabilized, within 4 years.

To give continuity to the plan and provide it with more personnel resources, different selective processes have been called and two training courses in composting have been carried out during 2017 and 2018.

4.2 Progress of REVITALIZA

Thirty-seven municipalities adhered to REVITALIZA, which represents 60.7% of the municipalities and 50.4% of the total population of the province. These municipalities are implementing the composting plan at different levels, either community composting or a municipal waste plan that includes home and community composting. The training and personnel selection activities have allowed 57 master composters who work at different levels and with different tasks and responsibilities. As part of the educational activities, 158 sessions were taught with 9448 participants, among students and teachers, in 51 educational centres.

The staff of the Provincial Council of Pontevedra actively participates in workshops, meetings, congresses, round tables, etc. that give visibility to REVITALIZA and allow to establish synergy with other institutions. REVITALIZA appears regularly in local and regional media reporting on the different events and activities that take place. These publications make it possible to give visibility to the plan not only at local and regional levels but also at national and international levels. Likewise, the neighbours and small producers who participate in composting serve as an example for the rest of the citizens, which allows to gradually involve more sectors of the municipality.

Next, the main results and advances of local composting are presented. Regarding the small composting facilities, the Provincial Council staff is making contacts with waste management companies with the aim of assuming the municipal bio-waste that cannot be managed by home and community composting.

4.2.1 Home composting

The first deliveries of individual composters started in the spring of 2018. As can be seen in **Table 3**, 37% of the composters expected delivery have been distributed in the five participating municipalities. The staff of the Provincial Council conducts door-to-door visits to collect data on the residents (address, number of family members, bio-waste management, etc.) in the areas of the municipalities that could manage the bio-waste by means of home composting. It should be pointed out that in more rural communities, traditional recovery of household waste at the household level, home composting and animal feed have diverted a part of bio-waste from municipal waste management system [14]. For this reason, a part of the rural population generates a small amount of bio-waste because of on-site reusing, to which one must add the second homes and the phenomenon of rural depopulation.

The master composters call the interested residents of the neighbourhood in which they are going to carry out the training and the delivery of composters. The training activities have been well received, with a percentage of attendance of 60% and an average of 33 composters delivered in 44 training activities.

During the follow-up visits to the home composters, the staff of the collaborating associations has solved doubts and established the necessary corrective measures related to the development of the composting process. The main incidents observed were the scarce quantity or lack of bulking agent and low moisture conditions of the composting material.

There is currently not enough data available to estimate the amount of bio-waste managed through this line of action. In [15], it has been estimated that in urban areas, where homeowners have access to garden space, home composting could potentially divert 20% of the biodegradable household waste stream from landfill disposal if approximately 20% of the community were actively engaged in home composting. The Provincial Council is studying the methodology to establish the amount of organic fraction treated in composters and, therefore, determine the contribution of home composting in bio-waste recycling.

4.2.2 Community composting

In November 2018, 76 CCCs formed by 535 modular units were in operation, spread over 28 municipalities in the province of Pontevedra. The master composters regularly visit CCCs, record the process parameters, such as temperature and changes in volume over time, and proceed to mix and turn the material between modular units, among other activities.

As previously mentioned, the work method allows the development of the composting process in three modular units. **Figure 5** shows the temperature profile of a

No. of home composters expected delivery	4186
No. of home composters delivered	1558
No. of training activities carried out	44
No. of home composters delivered/training activity	33
% of Participating neighbours/total neighbours called	60.0%
% of First visits/total home composters delivered	50.4%
% of Second visits/total home composters delivered	8.6%

Table 3.
Results of home composting in the five participating municipalities during 2018.

neighbourhood CCC and a small producer CCC, already settled in the population, during the monitoring of the process in the three units. The temperature profiles of both CCCs showed patterns typical of the composting process, in other words, temperatures increasing to thermophilic levels (>45°C) followed by maintaining said temperature and a subsequent decline in temperature until reaching mesophilic levels. Thermophilic temperatures were maintained for 65 days and 50 days in the neighbouhood CCC and small producer CCC, respectively. Despite these differences, compost hygienization was ensured by continuously maintaining temperatures above 55°C for more than 15 days [16]. In general, all CCCs reach high temperatures in the bio-waste input unit, although the development of the process will depend on numerous factors. Although, material in community composters are more isolated than the material present in home composters, the environmental changes can affect temperature development (periodic access for bio-waste input and for process control tasks). Another factor that affects the process is the type of bio-waste: uncooked and cooked waste. The biodegradation of recalcitrant compounds accelerates after the cooking process. On the other hand, [17] observed that when large amounts of waste were added at each feeding, compost temperature and maturity increased.

In the case of small producer CCC, it is observed that, after the turning of material from modular unit 1 (bio-waste input) to module 2 (homogenization), there was

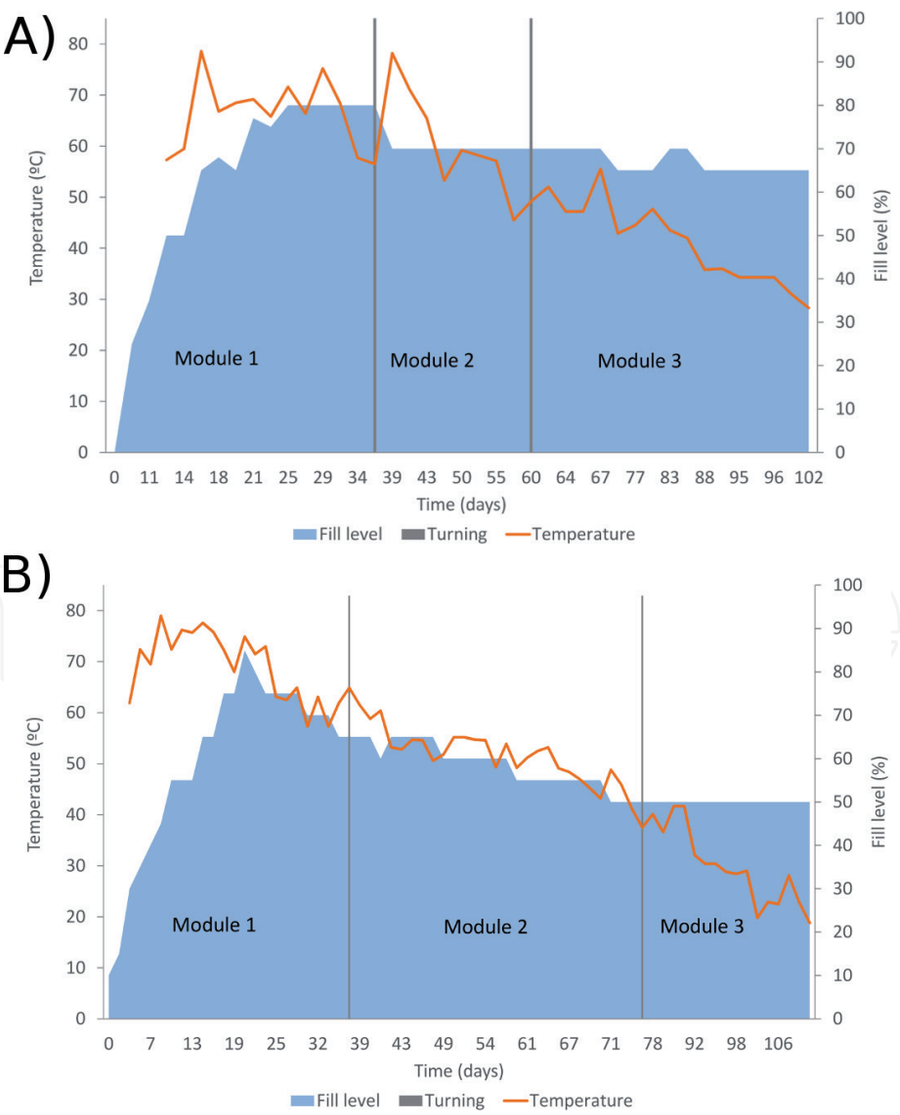


Figure 5.
Evolution of maximum temperature, fill level and turning during composting in the three modular units of (A) a neighbourhood CCC and (B) a small bio-waste producer CCC.

a rise in temperature. The master composters perform deep or superficial mixing of the composting material according to the conditions of the process. Although, the transfer of material from one module to another allows greater aeration and homogenization, which can facilitate an increase in temperature. In both temperature profiles, the phases or stages discussed above are distinguished: intensive degradation and temperature rise to thermophilic conditions (stage 1), less intense decomposition with maintenance and/or decrease in temperature (stage 2) and progressive decrease in temperature and maturation of the compost (stage 3). After the process, the compost presents homogeneous appearance (soil-like material), dark brown colour and a pleasant earthy smell (**Figure 4**). To facilitate the use of the product as fertilizer, potting soil or organic amendment, it is necessary to sift it.

Next, the analysis data of 76 composts sampled during the years 2017–2018 are presented (**Table 4**).

In general, composts showed high contents of organic matter, although the self-heating tests showed stability values indicative of mature compost. Important variabilities were observed among the compost for some parameters, such as electrical conductivity, ammonium and nutrients. The quality of municipal waste compost is dependent on many sources of variation including the composting facility design, feedstock source and proportions used, composting procedure, and length of maturation [18]. The different composition of the bio-waste affects the physicochemical characteristics of the compost. The high ammonium content could be a consequence of problems of degradation of the organic matter during the composting process due to a lack of moisture. However, only one sample had higher ammonium values than those considered suitable for compost 400 mg kg^{-1} [19]. Regarding electrical conductivity, high values were detected (78% of the samples with a conductivity higher than 2 dS m^{-1}). The use of compost must be controlled so as not to have negative effect on plant growth, although the compost of municipal waste usually presents electrical conductivity values between 4 and 8 dS m^{-1} [18]. As for pathogen content, 7.9% of the samples presented values higher than that established by the legislation for *E. coli* while *Salmonella* spp fulfilled the required level in all the samples.

	Mean	Standard deviation	Legislation limit	Recommended values
Moisture (%)	62.88	10.98	<40%	
Organic matter (%)	72.71	10.63	>35%	
pH	7.65	0.96	—	>7
Electrical conductivity (dS m^{-1})	3.39	2.32	—	<8
NH_4^+ (mg kg^{-1})	69.12	75.04	—	<400
CaO (%)	3.68	1.95	—	—
K_2O (%)	1.51	0.53	—	—
MgO (%)	0.43	0.49	—	—
P_2O_5 (%)	0.73	0.39	—	—
FeO (%)	0.38	0.28	—	—
Maturation degree	IV–V	—	—	IV–V
Salmonella spp (in 25 g)	Absence	—	Absence	—
Escherichia coli (CFU g^{-1})*	131.04	317.07	<1000 MPN	—

**N= 67 samples.*

Table 4.
Physicochemical parameters in compost from community composters (N = 76) during 2017 and 2018.

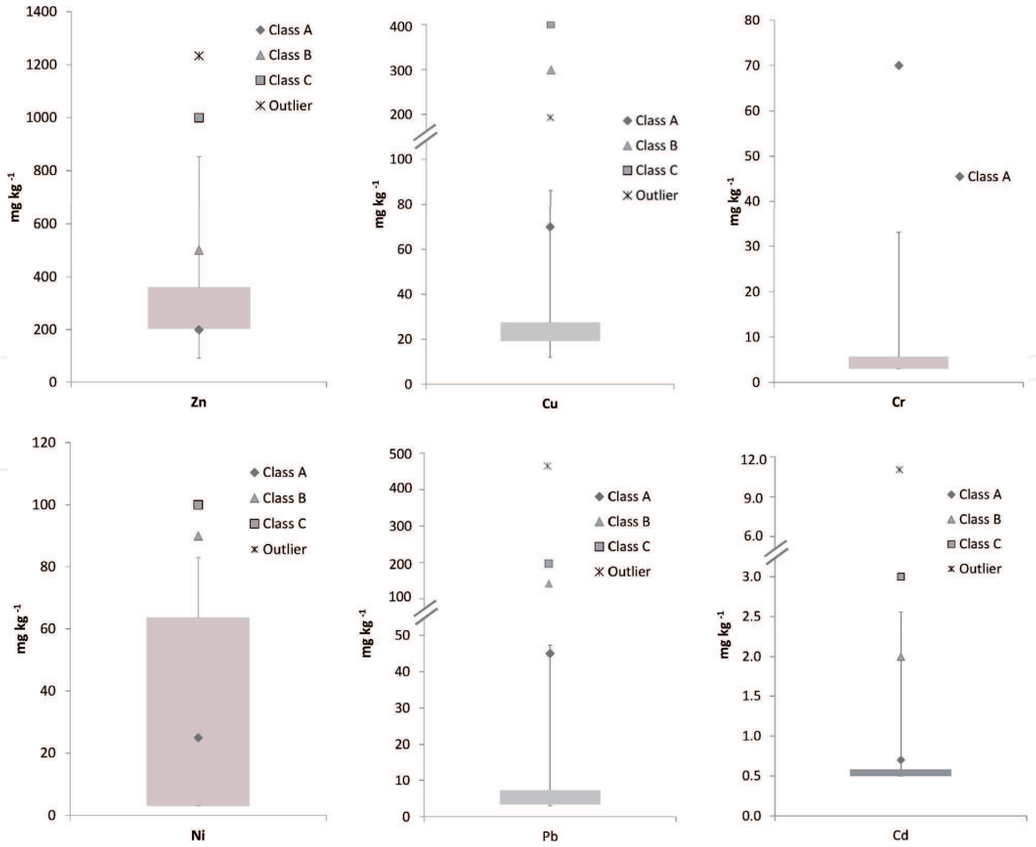


Figure 6.
Box plots of concentration data for six heavy metals in 76 samples of compost from community composting centres (CCC).

The Spanish legislation on compost [20] classifies compost into three categories according to the heavy metal content: Class A, B and C. **Figure 6** provides information on the variability in the heavy metals concentration indicating the respective classification categories. The atypical data observed for Zn, Pb and Cd correspond to different compost samples with a metal concentration 4 times (Zn), 7 times (Cu) and 52 times (Pb) above the mean values and, hence, they are considered outliers from analytical errors. Without taking into account samples with outliers, it is observed that 17.81% of compost belongs to Class A, 75.34% to Class B and 6.85% to Class C. For the last class, the metals Zn (4 samples) and Cd (1 sample) are those that exceed the thresholds of the regulations. There is a consensus in the scientific literature that aerobic composting processes increase the complexation of heavy metals in organic waste residuals and that metals are strongly bound to the compost matrix and organic matter, limiting their solubility and potential bioavailability in soil [21].

If we consider heavy metals separately, all samples belong to Class A for Hg (<0.4 mg kg^{-1} in all samples), Cr and Ni, while more than 96% of samples meet the levels for Class A in Cu and Pb concentrations. In 66.07% of Class B compost, Zn levels determine its classification. The presence of these heavy metals in the final compost may have different sources. In [22], it was concluded that the heavy metal content of the compost can be affected by the pollution of diverse exogenous sources and their origin can be found in the auxiliary materials used, the environment, the process or the storage method used. The possible sources of Zn are being evaluated to determine the necessary actions that reduce its content in the compost.

In **Figure 7**, the estimation of bio-waste treated in the CCCs of the province of Pontevedra is presented since the implantation of the first centres until the first semester of the year 2018. The quantities of treated bio-waste were calculated from the data of filling level of the CCCs, percentage of volume reduction over time

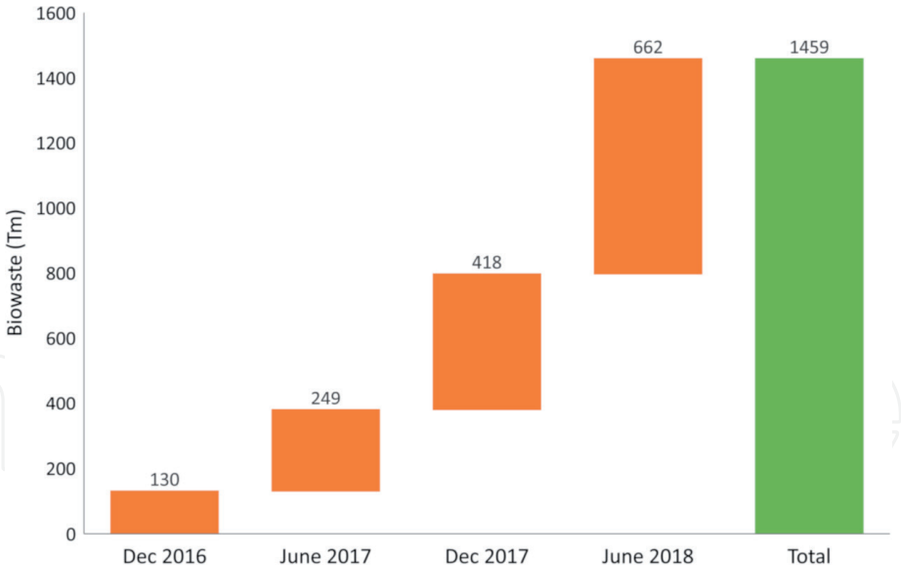


Figure 7.
Estimation by semester of the amount of bio-waste (including the vegetal fraction used as bulking agent) and the total amount accumulated in the CCC implemented in the province of Pontevedra.

and densities of the different materials. The bulking agent: food waste ratio 1:1 in volume was considered.

Finally, it should be noted that community composting have transformed, through a biological and aerobic process, about 1459 tonnes of organic waste and vegetable remains, into a biologically stable material that can be used as a soil amendment. This reduces the impact of bio-waste on the environment and makes possible the use of the resources that it contains.

5. Conclusions

The Provincial Council of Pontevedra promotes a change of model of waste management through the implementation of composting as treatment of the organic fraction generated in the municipalities, reducing the collection and transport services and the environmental and economic problems associated with them.

The new model has been designed to respond to the particularities of the province and the municipalities that compose it, so that it adapts to the population distribution characterized by dispersion in rural areas. This fact, together with the priority of compliance with the principle of proximity in the waste management, has made it possible to move towards a decentralized model based on the local composting of bio-waste at the municipal level. The provision of personal resources, and not only material resources, presented by REVITALIZA is a fundamental and necessary axis that demonstrates that the waste management projects developed by the administrative entities must be accompanied by training and raising of awareness to be accepted by the citizens.

Local composting allows the treatment of the bio-waste of the household and small producers on site. Bio-waste ceases to be part of the collection, transport and treatment line of the mixed fraction, thus reducing the environmental implications caused by its centralized management.

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