WASTE MAP OF THE PROVINCE OF CASTELLON

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Abstract

The problem of the ever-increasing generation of waste becomes more acute with inadequate environmental management, leads to environmental problems and highlights the ineffectiveness of society when using its resources.

This paper presents a study to assess the current situation of generation and management of waste in the province of Castellon (Spain). The study involves the creation of an inventory of waste produced in each municipality in the province, including different waste categories and their breakdown by fractions. The destination of the different types of waste and the treatments applied to them are also determined.

A Geographic Information System (GIS) is used to carry out this study. This enables the integration of spatial and alphanumeric information related to both the sources of waste generation and waste treatment facilities. The GIS enables geographical representation of the data collected on thematic maps, and provides tools for spatial analysis of these data. Spatial analysis is useful for locating problems in waste management and proposing strategies to improve the present situation.

Finally, a web map viewer is developed in order to disseminate the results. The web viewer provides access to the digital maps on waste obtained from the study.

Keywords: *Waste map; Waste management; Geographic Information System; Web map viewer.*

1. Introduction

There are numerous threats to the environment, but some of the most serious are those arising from the ever-increasing generation of waste in industrialized societies. This is a growing problem that is exacerbated by inadequate environmental management of waste. There are several risks associated with incorrect waste management: contamination of soil, water and air; impact on biodiversity and ecosystems; impact on landscape; natural resource depletion; and damage to the population (Strange, 2002). In short, poor waste management is a problem for two reasons: on the one hand, it may cause environmental impacts and harm to health; and on the other hand, it shows the ineffectiveness of societies when using their resources.

In order to address the problem of waste, environmental management should be carried out in a realistic and sustainable way. This involves considering waste as a source of raw materials instead of unwanted rubbish. Waste management should therefore prioritize their reclamation. In this respect, effective waste management may be a new source of employment and a substantial opportunity for economic development (North, 1997).

In recent years, developed countries have begun to take measures focusing on sustainable development. The European Union (EU) has announced the need for appropriate waste management and has established environmental objectives and targets to be met by Member States in the near future.

The study "Waste Map of the province of Castellon" (Vidal et al., 2009) aims to assess current waste management in the province of Castellon (Spain) and to ascertain whether this management is in line with environmental objectives for ensuring effectiveness. In addition, in cases where management is assessed as being ineffective (i.e. it fails to meet the environmental targets), the causes are researched and potential solutions to improve the management and achieve the environmental objectives established are proposed.

The first step in this study is to determine current waste generation and the geographical distribution of that generation. To that end, an inventory of the waste produced in each municipality in the province was compiled, covering different waste categories and their breakdown by fractions. The environmental management (consisting of collection, transport and treatment) currently applied to the inventoried waste was also determined. The data on waste generation and waste management were subsequently used as an input in a Geographic Information System (GIS), which enables the integration of spatial and alphanumeric information related to both the sources of waste generation and the waste treatment facilities. The GIS enables the representation of the geographical distribution of the data collected by means of thematic maps, and provides spatial analysis tools to take full advantage of the information available. In this way, the GIS simplifies the analysis of the current situation and makes it easy to locate problems in waste management. Potential management strategies for improving the current situation are therefore proposed. Finally, a web map viewer is developed, where digital maps on waste can be consulted.

2. Aims

The aim of the current study is twofold:

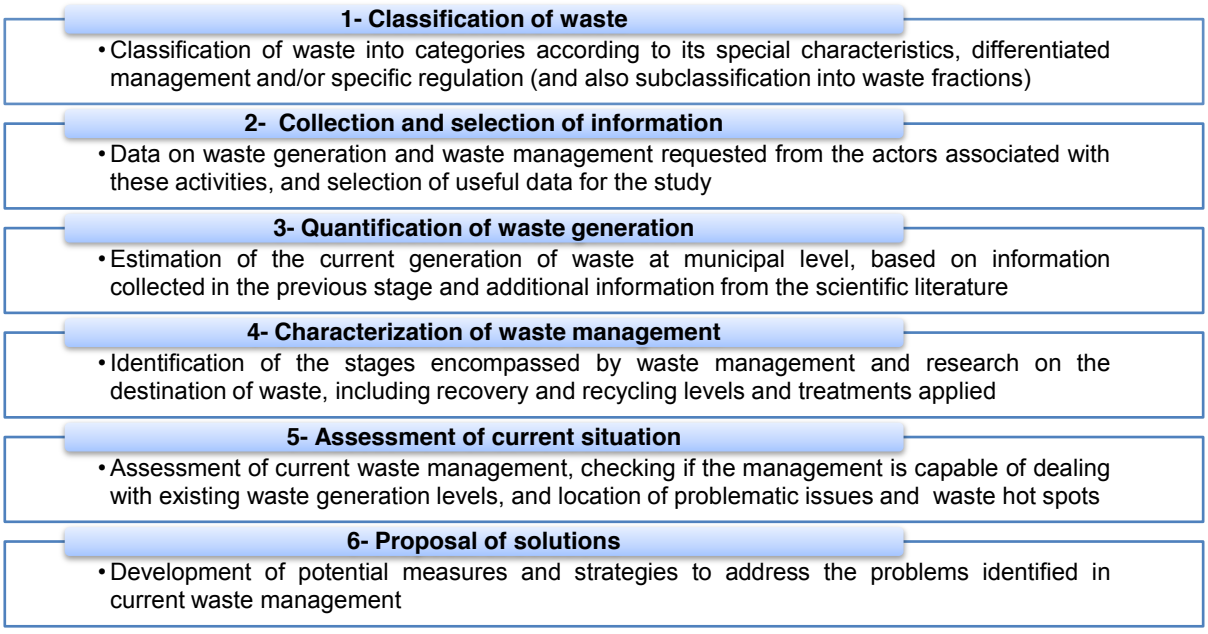
- To assess to what extent the current management of waste in the province of Castellon can provide a sustainable answer to the existing generation of waste.
- To propose new alternative solutions for those cases in which the current environmental management of waste is not appropriate and/or is assessed as improvable.

This study is funded by the Castellon Chamber of Commerce, Industry and Shipping, which is also interested in discovering new business opportunities in some of the solutions proposed.

3. Methodology

The methodology used in the study is shown in Figure 1.

Figure 1: Methodology applied in the study



The stages carried out in study are explained below.

3.1. Classification of waste

Firstly, a classification of the waste that will be subject to study is made taking into account their special characteristics and their differentiated management methods, which lead to specific regulation in some cases. In this way, the following waste categories are distinguished:

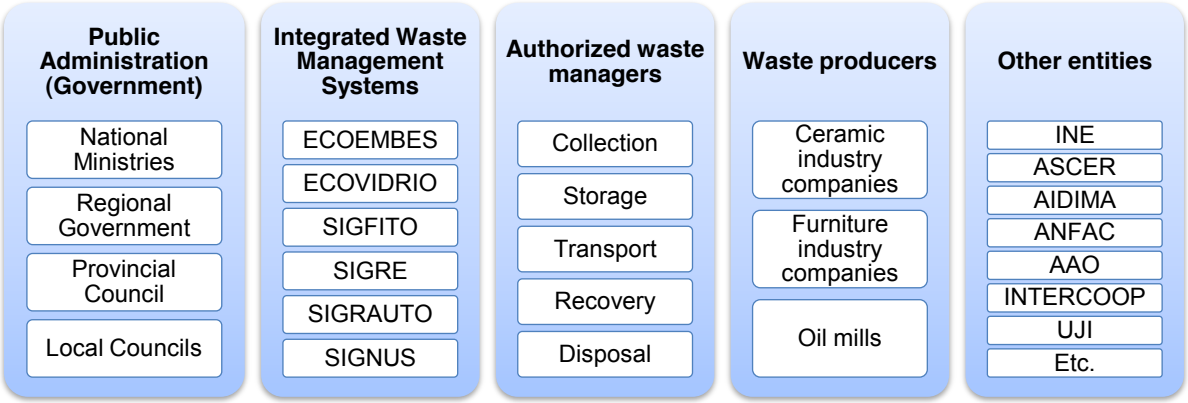
- Municipal solid waste.
- Agricultural waste.
- Livestock waste.
- Forest residues.
- Health care waste.
- Waste from sewage treatment.
- Construction and demolition waste.
- Ceramic industry waste.
- Furniture industry waste.
- End-of-life vehicles.
- End-of-life tyres.

These waste categories are in turn composed of several fractions. The study takes this subclassification into account and, as far as possible, attempts to characterize and quantify the different fractions encompassed by each waste category.

3.2. Collection and selection of information

Once the waste categories to be studied have been identified, all possible information on the generation and management related to these waste categories must be collected. The sources of information providing data for the study are shown in Figure 2.

Figure 2: Sources of information on waste



The information collected is organized appropriately and the quality and validity of the data checked, so that only the information that is useful for the study is selected. Since the study requires a municipal level of detail, the most important data are usually provided by the actors directly linked to the generation and management of waste in each municipality, namely waste producers, local and provincial Councils, Integrated Waste Management Systems and authorized waste managers. Nevertheless, some data from other sources are also useful to estimate and compare the results obtained.

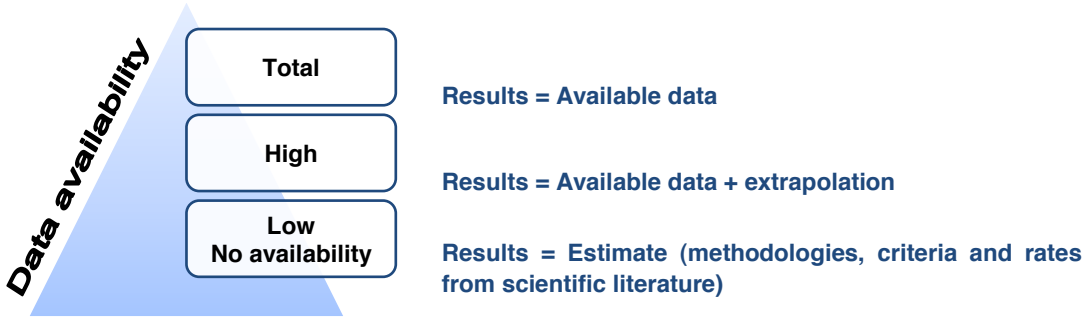
3.3. Quantification of waste generation

The information collected in the previous stage is used to quantify the amount of waste generated in each municipality. There are only a few waste categories in which the data collected cover all the municipalities in the province. In fact, information on waste generation for some waste categories is very limited. In these cases, in order to overcome the lack of data, estimates of waste generation are performed as follows (Figure 3):

- For waste categories in which real data are available for many of the areas under study, rates of waste generation are computed and these values are extrapolated to the other areas in which waste generation is unavailable.
- For waste categories in which the availability of real data is limited or non-existent, estimates of waste generation are performed based on methodologies, criteria and rates extracted from other similar studies.

The waste generation results are compared with data from other sources. The Waste Inventory of the Community of Valencia (ICRCV, in Spanish) provides an estimate of the waste generated in each municipality of the Valencia Autonomous Region in 2002, 2003 and 2004 (CMAAUV, 2002-2004). Since the IRCV provides data disaggregated by municipality and covering recent years, this inventory is the main source for checking most of the results on waste generation for the study presented herein.

Figure 3: Procedure for quantifying waste generation



3.4. Characterization of waste management

The classification of waste into categories composed of several fractions is mainly due to the differentiated management methods applied to them. The different waste fractions within a certain waste category are usually managed separately as different waste streams, since they may require particular modes of collection, transport, storage or treatment, depending on their potential for recovery and/or hazardous properties.

Once the waste generation has been quantified, the environmental management that is currently applied to each waste category (or more specifically the management applied to the main fractions that compose them) is determined. To that end, data on waste management is requested from the actors who carry out these activities in the previous information collection stage. These actors are asked for information that is as disaggregated as possible, i.e. detailed information in accordance with the level of waste segregation for management. Interestingly, information concerning waste generation and waste management does not cover all the fractions within each waste category (according to the List of Wastes, see Annex of the Commission Decision 2000/532/EC), since the current separation of waste is not as specific. Nevertheless, a level of detail consistent with the current management of the different waste streams can be obtained using the data collected and the scientific literature. The various categories of waste are therefore characterized in terms of their composition, with a distinction between the main fractions and specification of the proportions in which fractions are presented, the levels in which they are recovered and the treatments applied to them.

3.5. Assessment of current situation

The completion of the previous stages enables to determine the current situation of waste generation and waste management in the province of Castellon. At this point, the current situation is assessed in order to determine to what extent the environmental management of waste is adequate.

First, current waste management is compared with the environmental objectives of the Integrated National Waste Plan 2008-2015 (PNIR, in Spanish). The PNIR (MARM, 2008) covers most of the waste categories included in this study. The PNIR establishes mandatory targets and other desirable targets

related to the recycling and recovery levels to be achieved in the near future, indicating the treatments to be applied to that end.

Second, the location and treatment capacity of the facilities that are currently available are studied in order to ascertain whether they are in fact able to deal with current levels of waste generation. To that end, the results of the previous stages are introduced into a GIS software, which makes it easier to obtain, manage, handle, analyse, model, represent and output spatially referenced data for solving complex planning and management problems (NCGIA, 1990). The GIS thus enables geographical representation of the results of waste generation for each municipality, which is then shown on the map of the province of Castellon. The waste treatment facilities can also be overlaid on this map, and it is therefore possible to assess whether the geographic distribution of the facilities is consistent with the distribution of waste generation, as required by the principles of self-sufficiency and proximity.

3.6. Proposal of solutions

As a result of the assessment of current situation, problems have been detected in the environmental management of certain categories or fractions of waste in the province of Castellon. In addition, the causes of these problems have been identified and located, as well as the waste hot spots (i.e. regions with waste management issues). Potential solutions are therefore proposed for cases in which the current environmental management of waste is inappropriate or is assessed as being improvable. The main measures and strategies envisaged are the establishment of new procedures for collection and treatment, the implementation of new treatment facilities, the promotion of the recovery of certain waste streams and the improvement of transport logistics.

4. Results

The results of the study, as well as the procedures carried out to obtain them, are included in the report "Waste Map of the province of Castellon" (Vidal et al., 2009):

- Review of legislative framework on waste, highlighting the principles and measures that ensure proper waste management.
- Description of the various waste categories in terms of their source, composition and management methods, emphasizing their ability to be recovered.
- Quantification of the annual generation of waste in each municipality in the province of Castellon, based on real data and appropriate estimates.
- Characterization of the current waste management in the province of Castellon, quantitatively specifying the types of collection, transportation and treatment.
- Assessment of the current situation of waste generation and waste management in the province of Castellon, identifying problems concerning environmental management.
- Proposal of measures and strategies to address the problems identified.

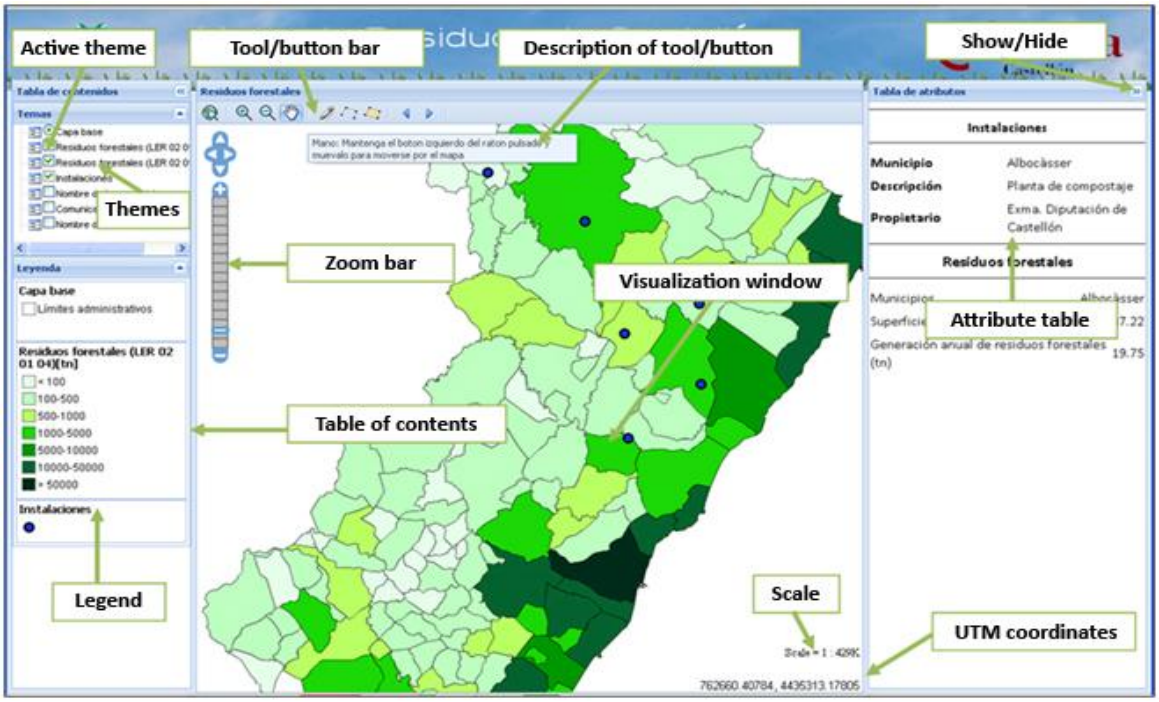
A summary of the most important results from the study is presented below.

4.1. Current waste generation: waste inventory and web map viewer

As a result of the present study, an inventory was compiled of the waste produced in each municipality in the province of Castellon, covering different waste categories and their breakdown by fractions. All data on waste generation were introduced in the GIS, which acted as the waste inventory database. The GIS not only provides storage and management of data, but also data analysis (both statistical and spatial) and geographical representation of the results by means of thematic maps. A wide variety of digital maps on waste generation by municipalities was thus developed for the various waste categories studied.

A web map viewer was also developed in order to provide easy and controlled access to the waste maps showing the inventory data. The characteristics of the web map viewer developed (available at http://www.gid.uji.es/MapaResiduosCastellon) are shown in Figure 4.

Figure 4: Web map viewer of the Waste Map of the province of Castellon



4.2. Current waste management

One of the main aims of the study is to assess to what extent current waste management in the province of Castellon can provide a sustainable answer to the existing amounts of waste produced. To that end, the environmental management that is currently applied to each waste category is assessed and compared with the environmental objectives established by EU and national legislation, which are included in the PNIR as recycling and recovery levels to be met in the near future (MARM, 2008). This leads to the conclusion that municipal solid waste, agricultural waste, construction and demolition waste and end-of-life vehicles have environmental management problems which make it impossible to achieve the environmental objectives of the PNIR. On the contrary, environmental management applied to waste from sewage treatment, ceramic industry waste, furniture industry waste and end-of-life tyres is in line with the objectives of the PNIR. Finally, the PNIR does not establish quantitative objectives related to livestock waste, forest residues and health care waste. However, as a result of the study presented herein, it can be concluded that the current management of livestock waste and forest residues is correct, while the management of health care waste is acceptable but needs some improvements.

Table 1 presents a summary of the current state of waste management in the province of Castellon, and identifies the following issues

MSW	High level of implementation of selective collection systems for glass containers, paper/cardboard and light packaging (ECOVIDRIO and ECOEMBES) Good level of recovery of glass containers, paper/cardboard and light packaging Correct operation of civic amenity sites available (also known as "household waste recycling centres") Lack of treatment facilities for MSW, especially in Baix Maestrat High activity in unauthorized landfills Lack of recovery treatments in the facilities for MSW, except for the facility in Onda (composting and recovery of materials prior to the disposal to landfill) Lack of civic amenity sites, especially in the interior of the province
AW	Excellent performance (good levels of collection and recovery) of the Integrated Waste Management System (IWMS) for containers of phytosanitary products (SIGFITO) Lack of monitoring and lack of recovery of pruning waste from agriculture Lack of monitoring and lack of recovery of waste plastics from agriculture

LW	Recovery of all LW (recovery as organic fertilizer) Good location and capacity of treatment facilities for LW (composting plants)
FR	Good level of recovery of FR (recovery in the wood, resin and cork industries; crushing and incorporation into soil; energy recovery; and composting with LW)
HCW	Correct treatment of HCW Good location of treatment facility for HCW of group III (service to Castellon and Valencia) Excellent performance (good levels of collection and recovery) of the IWMS for containers of medicaments (SIGRE) There are no treatment facilities for HCW of group IV in Spain (destination: treatment facilities in other EU countries) Overflow of the capacity of the treatment facility for HCW of group III
WST	High level of availability of sewage treatment service (99% of population served) Excellent level of recovery of sewage sludge (recovery mainly as organic fertilizer) There are no treatment facilities for sewage sludge in the province (destination: composting plants in Valencia and Cataluña)
CDW	Insufficient level of source separation of CDW Lack of treatment facilities for CDW, especially in Baix Maestrat Limited level of recovery of CDW
CIW	Good level of recovery of CIW (reuse at the ceramic industry) Good location of treatment facilities for CIW Medium level of source separation of CIW Overflow of the capacity of disposal facilities for inert waste in the short term
FIW	Excellent level of source separation of FIW Excellent level of recovery of uncontaminated wood waste (recycling for the manufacture of boards) Correct treatment of hazardous waste from the furniture industry Future availability of an energy recovery plant for wood waste from furniture industry near Baix Maestrat (under construction) There are no treatment facilities for uncontaminated wood waste in the province (destination: wood chipping plant in Valencia) Poor logistics of hazardous waste from the furniture industry (destination: sorting plant in Valencia and subsequent treatment in facilities outside the province, even though there are facilities in the province for this purpose)
ELVs	Lack of authorized treatment facilities for ELVs (ATFs) in the inland areas of the province (many ELVs are transported to ATFs outside the province as a result) Technological obsolescence and poor performance of ATFs Insufficient level of waste segregation in ATFs
ELTs	Good location of treatment facility for ELTs Good level of recovery in the treatment facility for ELTs (recovery of materials: metal, rubber and textile) Low level of reception of tyres from ELVs Operation of treatment facility for ELTs at 70% capacity

Note: MSW is municipal solid waste, AW is agricultural waste, LW is livestock waste, FR is forest residues, HCW is health care waste, WST is waste from sewage treatment, CDW is construction and demolition waste, CIW is ceramic industry waste, FIW is furniture industry waste, ELVs is end-of-life vehicle and ELTs is end-of life tyres.

4.3. Proposals to improve waste management

Another of the main aims of the study is to propose new alternative solutions for those cases in which waste management is not appropriate or is assessed as improvable. The potential measures and strategies to solve these problems are therefore devised taking the problems identified in the current waste management as a starting point.

Table 2 presents a summary of the proposed solutions, considering the following issues:

- Ranking of the different waste categories according to the priority required by the actions to improve their environmental management (first column in Table 2).
- Distinction within each waste category between primary and secondary actions according to the priority required (second column in Table 2).
- Assignment of the responsibilities to carry out the proposed solutions, establishing whether the actions require government intervention and/or whether they can be undertaken by private enterprise (third column in Table 2).

Table 2: Proposals to improve the waste management in the province of Castellon

1 MSW	1 Implement new treatment facilities for MSW (material recovery lines and disposal of rejections to authorized landfill) with priority in Baix Maestrat (possible implementation of the facilities proposed by the Regional Waste Plans of the Community of Valencia) 2 Increase the availability of civic amenity sites with priority in the inland areas in the province (implement civic amenity sites in the car parks of shopping centres and/or mobile civic amenity sites)	
1 CDW	1 Implement new treatment facilities for CDW (sorting lines and material recovery lines and disposal of rejections to authorized landfill) with priority in Baix Maestrat (possible implementation of the facilities proposed by the Regional Waste Plans of the Community of Valencia) 1 Establish policies requiring the use of recovered materials from CDW (mainly recycled aggregates) for application in construction projects 1 Use mobile crushing and sorting plants for source separation and recycling of CDW in construction works	
2 CIW	1 Expand the current facilities for disposal of inert waste or implement new facilities (location in old mines, quarries or other degraded areas) 2 Promote the recovery of fired ceramic waste (recycling for the manufacture of chamottes, recycled aggregates, etc.)	
2 AW	1 Use mobile chipping plants for crushing pruning waste in crops themselves (possible coordination of the service through agricultural cooperatives) 1 Promote the sale of pellets from pruning waste to employers and individuals for energy recovery (possible sale through agricultural cooperatives) 1 Recover energy from pellets of pruning waste in waste incinerators (possible coverage of the capacity of the future energy recovery plant for wood waste from the furniture industry) 2 Establish selective collection of LDPE, HDPE and PVC from agriculture (possible collection by agricultural cooperatives) 2 Promote the use of bioplastics in the agricultural sector 2 Promote the recovery and recycling of waste plastics from agriculture or, alternatively, energy recovery (possible compensation for farmers who certify good agricultural and environmental practices)	
3	1 Increase the capacity of the treatment facility for HCW of group III or implement a new facility in Valencia	

HCW	2 Implement a treatment facility for HCW of group IV in the Valencia Autonomous Region to provide service to several provinces and/or regions	
3 ELVs	1 Implement ATFs with modern technologies (high performance and good levels of waste segregation and waste recovery)	
4 FIW	1 Future availability of an energy recovery plant for wood waste from furniture industry near Baix Maestrat (under construction) 1 Implement a recycling plant (wood chipping for the manufacture of boards) or an energy recovery plant for wood waste in La Plana (possible coverage of the capacity of the energy recovery plant with household goods and pruning waste from agriculture and forest) 1 Promote the source separation of hazardous waste in all furniture companies in order to transport them directly to treatment facilities within the province (possible avoidance of transport to Valencia for waste sorting prior to treatment)	
4 WST	1 Implement recovery plants for sewage sludge in the province 1 Promote the recovery of sewage sludge as organic fertilizer (encourage farmers in the province)	
5 ELTs	1 Increase the receipt of ELTs at the treatment facility through the collection of more tyres from ATFs and from other provinces (possibility to increase the input of ELTs by 30%)	

Note: MSW is municipal solid waste, AW is agricultural waste, HCW is health care waste, WST is waste from sewage treatment, CDW is construction and demolition waste, CIW is ceramic industry waste, FIW is furniture industry waste, ELVs is end-of-life vehicle and ELTs is end-of life tyres.

5. Conclusions

The study "Waste Map of the province of Castellon" (Vidal et al., 2009) aims to assess current waste management in the province of Castellon and ascertain whether this management is in accordance with environmental objectives to ensure effectiveness. As a result of the assessment, it can be concluded that municipal solid waste, agricultural waste, construction and demolition waste and end-of-life vehicles are managed in a way that is far from effective. On the contrary, the management applied to health care waste, waste from sewage treatment, ceramic industry waste, furniture industry waste and end-of-life tyres is adequate. However, some environmental management issues related to these latter waste categories could be improved. Only livestock waste and forest residues are currently managed in a completely efficient manner, since they are fully recovered and used within the province itself.

In general, the most alarming waste management problems in the province of Castellon are related to the lack of adequate treatment facilities within the province and the unbalanced geographic distribution of those in existence. This situation is contrary to the principles of self-sufficiency and proximity, which should guide correct waste management. In the best-case scenario, these problems lead to high costs of waste transport, in both economic and socio-environmental terms. In the worst-case scenario, the lack of waste treatment facilities leads to uncontrolled dumping, which involves numerous environmental risks. These problems are especially serious in the case of municipal solid waste and construction and demolition waste, due to the large amounts of waste generated. In order to address this situation, the solution is to implement the waste treatment infrastructure proposed by the Regional Waste Plans of the Community of Valencia (CMAAUV, 2001, 2002, 2004), which were approved more than five years ago, as soon as possible.

Another problem observed repeatedly in many of the waste categories studied herein is the limited level of waste recovery in the existing treatment facilities. This is mainly due to three reasons:

- The waste treatment facilities are inefficient because they do not have the technical means to recovery the most waste. This is true of the authorized treatment facilities for end-of-life vehicles, where the solution to improve the efficiency of treatment facilities is to upgrade the equipment.
- The waste entering the treatment facilities does not receive any prior separation at source, making recovery not feasible in the facilities, as in the case of construction and demolition waste. In these cases, the solution is to encourage separation of waste at source. This solution is one of the strategies that must be widely promoted and should be applied to any category of waste. Evidence benefits of source separation can be observed by the good levels of recovery of the waste managed through Integrated Waste Management Systems.
- There is no competitive market for materials recovered from waste, and as such no interest in waste recovery. In these cases, the use of recovered and recycled materials must be promoted. In addition, new markets and synergies between sectors should be researched in order to incorporate these materials, such as energy recovery of waste streams either in industry (cement boilers and blast furnaces) or by individuals (fireplaces in homes).

On the other hand, in some cases we found that some waste streams are transported to treatment facilities which do not fall within their geographical area. For example, hazardous waste from the furniture industry is transported to treatment facilities in Valencia, despite the existence of facilities able to provide the same treatment in the province of Castellon. In that respect, an important waste management issue involves transport logistics. The transport logistics of waste must be oriented not only to avoid unnecessary transport of waste, but also to find synergies within the same sector and between different sectors, in order to reduce transport costs as well as environmental and social impacts.

In conclusion, the main measures and strategies envisaged to improve the current situation of waste management in the province of Castellon are the establishment of new procedures for collection and treatment, the implementation of new treatment facilities, the promotion of source separation and recovery of certain waste streams and the improvement of transport logistics. The solutions proposed in the present study are an initial first qualitative approach to the improvements that should be applied to current waste management. The study therefore provides a strategic line for planning more specific measures. Taking this line as a starting point, the next step will be to perform comprehensive assessments of specific solutions, and to study their technical feasibility and their economic and socio-environmental impacts, in order to establish the final solutions.

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