Management and Valorisation of Protective Equipment constituted by Polypropylene in Hospital Environment

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ABSTRACT

In a hospital environment, keeping a sterile and uncontaminated surrounding is essential and that requires practices such as, the use of personal protective equipment's such as disposable white coats, surgical caps and surgical cloths used by healthcare professionals or the users of that services to prevent the risk of spreading infectious agents during medical procedures. However, the use of this type of disposable materials leads to the production of waste which currently has as final destination its disposal.

The work to be done will have as objectives secure the estimated value, to analyze management alternatives and economically viable technologies that are able to promote the circular economy of the polypropylene by means of preparation for posterior reuse as a secondary raw material, insitu or in dedicated ex-situ units . In addition to the many challenges associated with plastic recycling and derived materials, in the hospital sector, it is necessary to have in mind the specific characteristics of the products design that are conditioning factors for the reprocessing, the communication and the procedures effectiveness for the primary screening of those products and last but not the least, the eventual limitation of spaces and infrastructures within the hospitals that can limit the disintegration of recyclable materials and it's valorization in-situ.

In this work, the chemical and physical analysis of the protective equipment was carried out, as well as the mapping of the hospital wastes streams. For the analysis and evaluation of the proposed project a financial and SWOT analysis was also carried out.

The aim is to address this thematic in an integrated, multidisciplinary and innovative way, which can not move forward without the main stakeholder's.

Keywords:

Personal Protective Equipment; Hospital Waste Management; Polypropylene; Non-Woven Fabric; Hospital Waste Valorization.

Abbreviations

APA – Agência Portuguesa do Ambiente
Approx. – approximately
RDF – Refused-Derived Fuel
CIVTRHI - Centro Integrado de Valorização e Tratamento de Resíduos Hospitalares e Industriais (Integrated Center for the Valorization and Treatment of Hospital and Industrial Waste)
DGS – Directorate-General for Health
e-GAR – Electronic Waste shipment document
HW – Hospital waste
INE – National Statistics Institute
LCA – Life Cycle Assessment
ELR – European List of Residues
MIRR – Integrated Map for Waste Registration
NWF – Non-woven fabric
WHO – World Health Organization
WMO – Waste Management Operator Hospitalares (Hospital Waste Manager)
HHV – Higher heating value
PERH – Strategic Plan for Hospital Waste
PE - Polyethylene
PP – Polypropylene
PPE – Personal protective equipment
RGGR – Regulamento Geral da Gestão de Resíduos (General Regulation of Waste Management)
SIRER – Sistema Integrado de Registo Eletrónico de Resíduos (Integrated Electronic Waste Registration System)
SSADM - Structured Systems Analysis Design Method
SWAP - Strategic Waste Achievement Program
RDI – Research, development and innovation
EU – European Union
UW – Urban Waste
VOCs – Volatile organic compounds

1 INTRODUCTION

Disposable personal protective equipment (PPE) used in health care units are produced from non-woven fabric (NWF) usually made of polypropylene (PP) and viscose, which confers impermeability and non-toxicity, preventing the passage of contaminating fluids. NWF is a material used for medical and therapeutic first-aid, clinical or hygienic purposes. To the health care professionals, hospital authorities and patients it is of utmost importance the level of protection offered by the material, whether to liquids or to the microbial flora. oferece.

NWF applications are vast and with particularity in the hospital environment, where it is possible to find this material in disposable white coats, caps and shoe covers; In the operative block there are also several equipment made of NWF, such as surgical material coating.

The NWF density varies according to the type considered; for instance, a NWF composed of PP has a density of 0.91 g/cm3, whereas if it is made of polyester that value is of 1.38 g/cm3(11). Thus, the properties of a particular NWF may vary and are dependent upon various factors, such as the type of fibers used, the arrangement of the fibers, the type of consolidation process and its agent. Accordingly, the NWF that is obtained may be rigid or soft, exhibiting different degrees of strength resistance and thus having or not a disposable nature, as it is for most of the NWF of hospital origin or, on the contrary, be a material with a long lifespan, for example, reusable non-woven bags (15).

1.1 POLYPROPYLENE STRUCTURE AND PROPERTIES

Polypropylene (PP) is one of the main constituents of disposable hospital PPE, such as white coats, caps and shoe guards. Considered as an unsaturated hydrocarbon, it only has carbon and hydrogen atoms in its composition and its formation results from the polymerization of propylene, a gaseous product resultant of the petroleum distillation.

1.2 LIFE CYCLE OF POLYPROPYLENE

PP products have a slow degragation when disposed in landfills, taking from 20 to 30 years to decompose completely (12). Thus, recycling this material represents an advantage at various levels.

In order for PP recycling to be economically viable, a number of factos has to be taken into consideration, such as dificulty and cost reduction associated to the PP recycling process. This process consists on several stages, namely the sorting, harvesting, cleaning, melt reprocessing and production of new products from recycled PP.

2 PROJECT: HOSPITAL WASTE MANEGEMENT OPERATION

2.1 PROJECT PRESENTATION

A project was developed whose main purpose is the end of landfill and dedicated incineration dedicated to disposable HW from group II and III (for example, it was estimated that approx. 300 t/year of PP only white coats, i.e., a small fraction of the disposables, according to studies by Lucas, (2016)), transforming them into PP bars, allowing their reintroduction in the market and, thus, promoting a circular economy. It is also intended to eliminate, in the Health Units, the waste of a raw material with high demand in the market, the PP.

The second objective of this project is to promote the cradle-to-cradle technical metabolism of the disposable PP, mainly in the upcycling regime, for which, in addition to the adequate implementation of the technology, the equipment acquisition and final product management model will be determinants.

This project is considered to be innovative at a national level, having already some experience in successful case studies in Austria and the United Kingdom, counting on the development and implementation of the technology base with two technological partners; the Thermal Compaction Group (TCG), which has pilot/commercial scale equipment and Instituto Superior Técnico that developed the idea and has experience in the RDI field of projects with the industry, in the waste management, in the transformation/ characterization of polymers and in control/monitoring of pathogens and VOCs.

The solution idealized in this project is based on the physical transformation of the waste with elimination/sterilization of biological risk contaminants and the production of PP bars with suitable fusibility index for reuse.

The recommended solution is environmentally friendly, since the virgin PP production emits approx. 1.4 Kg CO_2/kg of PP, with an electric consumption of 0.5 kWh/kg, while CO_2 emissions in the recommended treatment process are negligible and the electricity consumption is estimated in the order of the 0,5kWh/kg of PP (Rem, 2009).
This project has potential impacts, particularly for the parties involved. At a short and medium term, economic impacts are expected, such as the creation of a new business model that not only boosts the creation of new jobs, but also the substantial reduction of HW numbers in groups II and III, constituted by PP, whose final destination currently is dedicated incineration.

At an environmental level, this project reflects positive impacts from a high economic, social and environmental character, since inadequate storage or inadequate transport of these HW can put public health and the environment at risk. The reintroduction of the raw material in the market, that cames from the remanufacturing of the PP, allows not only the re-use of resources, but also the circular economy promotion avoiding the emission of greenhouse gases in the reprocessing compared to the virgin material production and that, that would occur upon its elimination.

For this project, a study area was defined that includes the Centro Hospitalar Lisboa Central. For this exercise it was necessary to be consider the data available at the National Statistical Institute (INE) and the data provided by SUCH (Common Hospital Use Service). At INE, only the total data per region are available, therefore, it was necessary to consider the entire Lisbon metropolitan area, that is, 17 public hospitals were considered, that are aggregated by different Administration Centers. The analogy between the data collected (total by region) and the ones from the hospitals was made taking into account the number of beds of each unit. The number of beds per hospital unit is the study comparison basis.

2.2 METHODOLOGY

In a preliminary phase, several public hospitals in the Lisbon metropolitan area were contacted, namely Centro Hospitalar Lisboa Central, Centro Hospital Lisboa Norte, via various channels, such as SUCH, e-mail, telephone and in person, in order to obtain information about the production of HW and Personal Protective

Equipment (PPE). From the contacts made, it was intended to collect data on the following topics:

- Quantity of HW produced from each group;
- Frequency of collection of HW;
- Destination and type of treatment of HW collected;
- Quantity of PPE annually used;
- Services where PPE is most commonly used;
- PPE acquisition costs.

In order to obtain the amount of PPE annually used at a national level, several entities, such as SUCH, the Board of Directors of Centro Hospitalar Lisboa Central and Centro Hospitalar Lisboa Norte, Directorate-General for Health, Central Administration of Health Systems, APA and Regional Health Administration, were contacted, but in spite of that it was not possible to obtain the requested value. Consequently, an estimate was made from the data collected and the number of beds in each hospital unit was used as a reference point. The estimate was based on the results of a 2013 Stanford study. From this study an analogy was made between the number of hospital beds and the number of hospitalizations, outpatient regimens and spatial personnel working in each hospital unit. A disposable PPE consumption was then associated, based once again on the values of the Stanford study (2013).

For this work it was also necessary to carry out a bibliographical research, in order to find several solutions already existent in the market or at a study phase, regarding the management of disposable PPE. For this purpose, scientific articles, reports, market studies, Portuguese and European legislation were analyzed, being also taking into acount case studies and relevant companies, in order to obtain a better understanding of the feasibility of certain alternatives.

2.2.1 Higher Calorific Value Determination

The Higher Calorific Value (HCV) determination of disposable PPE has an objective of finding the viability of its routing to energetic recovery alternatives. In this technique, a sample portion of each article is placed in a calorimetric pump under high oxygen pressure conditions, thus promoting complete combustion. The method used is based on technical specification CEN / TS 15400: 2006.

Samples are prepared following a certain procedural order; the disposable PPE samples are weighed, cut into strips and frozen using liquid nitrogen, which facilitates grinding, and finally they are crushed in the blade mill. The equipment used in the laboratory is called Retsch SM200. The samples were crushed in three sequential cycles with 10, 4 and 1 mm sieves, with a square mesh with the contaminants (for example the elastic ones) properly removed.

After the samples preparation, pellets were formed using a manual press. The pellet is weighed, and is then placed in the crucible of metal bomb calorimeter and subsequently winded up the cotton yarn filament bomb calorimeter. The equipment used was the LECO AC600. After sealing the bomb, it is pressurized with 30 atm O_2 and the HCV is quantified. If residue formation occurs after the calorimetry test, it is weighed later.

2.2.2 Ash Content Determination

After samples pellets were burnt, the ones that presented a residue were subjected to the ash contente analysis. The sample is dried in an oven drying at 105 °C, where the porcelain dishes are heated in a muffle at 550 °C for a minimum of 60 minutes and then cooled in a metal plate for a few minutes. The dishes are then transferred to the desiccator, where they are cooled at room temperature. The muffle used in this experimental procedure was Nabertherm L3/S27.

The sample crucibles with the sample were weighed and placed in the muffle, with the heating ramp shown in Table 1.

Table 1 - Heating ramp used for the determination of ash content in PPE.

Temperature (^{O}C)	Time (Minutes)
0 - 250	50
250±10	60
250-550	60
550±10	120

The dishes are then removed and allowed to cool on a metal support for a few minutes, and are again transferred to a desiccator until they reach room temperature. The ash dishes were weighed, placed back into the desiccator and placed in the muffle at 550 °C for 30 minutes until a constant mass was reached.

To determine the dry ash content, expressed by the mass fraction as a percentage (%m/m), is given by equation (1), where $mprato + cinzas$ is the dish mass plus the ashes, in grams, $mprato$, $mprato + amostra$ is the dish mass with the sample, in g and H (%b. h.) is the moisture content on a wet basis, expressed as a percentage by mass.

(1)

$$Cinzas\,(\%\,b.s.) = \left(\frac{m_{prato+cinzas} - m_{prato}}{m_{prato+amostra} - m_{prato}}\right) \times 100 \times \frac{100}{100 - H\,(\%\,b.h.)}$$

2.3 HOSPITAL RESIDUE MANAGEMENT SYSTEMS MODELING

The hospital waste management systems modeling arises from the need to optimize the waste system to reduce environmental burdens and economic costs, improving social acceptability. The methodology serves to explain how the system works and allow better cooperation and communication among those involved in the decision-making process. The defined methodology allows the stakeholders to decide the best decision, given the circumstances, as well as to determine the most acceptable set of actions.

Considering the complete life cycle of HW, from waste prevention to final disposal, the entire cycle is part of the decision-making process.

For that, the Strategic Waste Achievement Program (SWAP) methodology was used, whose objective is to design a strategic tool that can be used in medium and large scale entities for waste management, in order to meet the needs and requirements of all parties involved. This methodology involves four steps: (1) the project scoping, (2) making a list of possible waste management actions, (3) selecting the most appropriate waste management actions, and (4) implementing of the agreed waste management actions.

In order to select the most appropriate management actions, we used the Structured Systems Analysis Design Method (SSADM), a methodology used by the United Kingdom for the government documents development related to information systems. As a result, a diagrammatic representation of the system is obtained and it can be used as a discussion document among all stakeholders. The following five symbols are presented in the schematics resulting from the work developed.

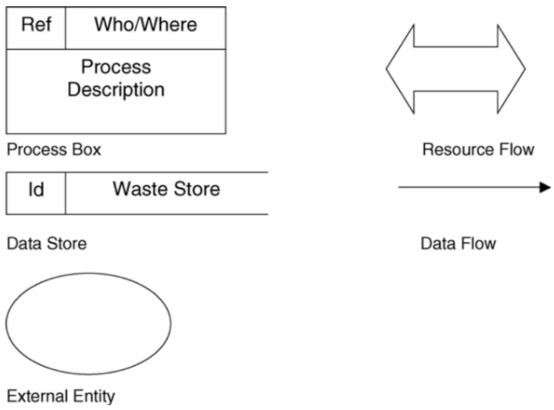

Figure 1 - Symbology used in the mapping of the waste stream

From analysis of figure 1, it is observed the external entity, which consists of a data stream source or destination that is outside the study area. The process box, on the other hand, demonstrates a data flows transformation or manipulation within the system; second, a location appears to the right of the identifier and describes where in the system the process occurs or who performs the transformation; a descriptive title should still be placed in the center of the box, preferably a simple and imperative phrase. The data flow shows the flow of information from the source to the destination; the information always flows to or from a process and can be written, verbal or electronic. The database acts as a data store for information inside the system. Finally, the resources flow shows the flow of any physical material from the point of origin to its destination. In the exercise performed, it was assumed that the data flow encompasses all types of flows that occur in a health care unit. In a hospital, all departments and units generate waste, however the generating rate is not equal between them. It is also important to know that there is a preference for reusable materials. As such, HW teams need to make strategic decisions based on the associated costs and the options available in the market.

For the project under study it is important to identify why and where the UWs and HWs of Group II and III produced in hospitals are being placed. The main techniques used to carry out the investigation were the observation of the visited sites and the interviews.

2.4 RECYCLING PROCESS "THERMAL COMPACTION GROUP"

The Sterimelt equipment developed by THE Thermal Compaction Group has a maximum capacity of 2m3 and in the operating phase it registers an average consumption of 5.5 kWh of electricity and can reach a maximum power of 15kW. In the course of the process, temperatures of around 280 °C can be reached, which translates into a final product free of contaminants, with considerable economic advantages, since hazardous HW management has higher costs compared to non-hazardous HW management[12]. This process also allows the reduction of volume waste by 85%, compacting it in blocks of easy transport.

Since the final product is in the form of PP bars, not in a granular form, the value of those bars is not so high when compared to the price of PP pellets. However, this technique has lower operating costs and the resulting bars can be sold at prices around 250€/t [12].

2.4.1 Finantial Analysis

The process under analysis is based on a simple technique and with low economic costs. However, a financial analysis is required in order to assess the feasibility of implementing the equipment in question. In the works developed by Lucas (2016) a financial analysis is performed in which the present work is based, changing and updating some parameters, given the current scenario. The following table shows the parameters related to the equipment characteristics and associated operating costs. associados.

Table 2 - Parameters considered for the feasibility analysis of the implementation of a TNT recycling equipment produced by the company Thermal Compaction Group.

Parâmetros	*Values*
Nº of weeks / year	51
Nº days / week	5
Nº cycles / day	10
Nº blocks / cycle	3
Mass/ PP block[1]	16 Kg
Market value of PP blocks[2]	200 €/t
Monthly salary (1 employee, 8 hours per day)	690 €/month
Average electricity consumption[2]	5,5 kWh
Cycle time period[2]	1,5 h
Cost kWh	0,17 €/kWh
HW collection rate	40 €/t
Licensing Cost	8 000 €
Equipment cost[2]	56 866,60 €

[1]Source: Lucas (2016). Average value; the mass of a block of PP is comprised between 12 and 20 kg;
[2]Value given by the company (Thermal Compaction Group), updated at the exchange rate (1 £ corresponds to 1.13733 €).

With the considered scenario, the equipment would process 122.4 t/year of PP. In order to follow up the process, an employee is required to perform tasks such as Group II and III materials composed by PP introduction in the equipment, handling and subsequent collection of PP blocks formed, as well as the energy consumption necessary for the equipment operation. Therefore, the expenses and revenues from the sale of the resulting PP bars were calculated considering the market value provided by Thermal Compaction Group, as well as the HW collection rate, approx. 40 €/t, since it is assumed that the value of the fee decreases, once the equipment can be housed in the premises of the respective hospitals, so it is necessary to adapt the current values (approx. € 60/t) to this new reality .

In this exercise two daily shifts are considered, as it is expected that only 25% of this employee's working time will be dedicated to operations related to the technique under analysis. Also considered are the charges on remuneration’s.

Considering the equipment acquisition through a loan at an interest rate of 4%, a lifetime of 10 years and assuming a market whose growth is 3% per year, also given that in the last 50 years there has been a growth in the consumption of disposable protective equipment in hospitals, the profitability criteria were calculated in order to determine the economic viability of the project, as can be seen in table 3. The expected growth also affects expenditure figures, since some of the parameters are directly dependent on the production values.

Table 3 - Profitability criteria calculated for an interest rate of 4%.

Profitability Criteria	**Interest rates** 4%	**Units**
Net Present Value (NPV)	72 223	€
Internal rate of return (IRR)	25,16	%
Pay Back Time (PBT)	4	years

3 Results and discussion

In order to determine its energy content, 17 disposable PPE articles were tested. The PPE analyzed were kindly provided by hospitals that constitute the Centro Hospitalar Lisboa Central, whose suppliers differ between the different hospital units, with up to more than one supplier in each hospital.

Table 4 - Description and characterization of the 17 samples of disposable EPI.

Sample Nº	Description	Sample Weight (g)	Weight Pollutants (g)
1	Green surgical field (with a waterproof part behind)	37,13	0,00
2	Mask (two units)	5,40	0,43
3	Duck's beak mask	4,33	1,90
4	White mask with respirator	3,52	4,20
5	Disposable pajamas (size L)	90,43	1,63
6	Dark blue regular gown	28,62	3,62
7	Light blue gowns (reinforced on arms and chest, size M, warm seams)	86,41	7,32
7.1	White reinforcement	25,41	0,00
8	Disposable white apron	12,60	0,00
9	Normal blue gown (size L)	89,25	9,66
10	Disposable foot protector	3,86	0,32
11	Mask with plastic visor (with aluminum wire)	4,94	6,32
12	Blue field (paper / plastic style)	7,32	0,00
13	Green cap (with seams)	2,00	0,39
14	Biberon (packaging and lid)	18,55	0,00
15	Light blue regular gown (XL size)	119,40	15,70
16	Light blue bat (reinforced on belly and arms with purple collar and cuffs, size L)	119,22	8,52
17	Biberon (pink part)	4,75	0,00

The samples were ground in three sequential cycles with 10, 4 and 1 mm sieves, and then subjected to contact with liquid nitrogen. When put in contact with liquid nitrogen, all samples of disposable PPE have hardened, however, the milling process is not fast enough and the effect of the liquid nitrogen is rapidly lost. In any case, it was possible to grind all existing disposable PPE.

The HCV of each sample was determined, being verified that after the combustion of the PPE from samples 10 and 13, the calorimeter crucible had a residual mass. In order to evaluate whether it was unburned waste or ashes, an analysis was carried out to the ash content of the four samples. The PPE of samples 10 and 13 had an ash content between 30 and 37%.

Figure 2 - Photograph of the crucibles with the residues resulting from the combustion of two samples, corresponding to test 1 and 2.

The detailed results of the various tests performed are available in the complete document.

From the obtained results interpretation, it could be concluded that the HCV of the disposable PPE regarding samples 10 and 13 is reduced due to the fact that in both tests the samples had a high content of ashes (30 to 37%), which glazed after combustion, justifying the presence of the solid residue obtained. Thus, depending on the type of disposable PPE, its residual fraction may or may not be significant, existing disposable PPE as in samples 10 and 13 which may have high ash content.

Considering only the fired fraction, it can be seen that the HCV of the various samples is very similar, being in the range of 44-48 MJ/kg. It can be seen that the NWF present on the gowns has a considerable calorific value, as expected, since plastics, and in particular PP, have a high energy content.

3.1.1 Hospital Waste Management and Personal Protection Equipment in the various Units

In order to better understand how HW management is carried out before they are collected and transported to the appropriate destinations, technical visits have been made to all hospitals in the Centro Hospitalar Lisboa Central, Centro Hospitalar Lisboa Norte and the Portuguese Institute of Oncology in Lisbon. The remaining Hospitals belonging to the Lisbon metropolitan area were also contacted via telephone and e-mail. The choice of the units contacted was based on a possible partnership with SUCH to create the pilot project.

Given that there are 35 hospitals in the metropolitan area of Lisbon, of which 17 are public hospitals and 18 are private hospitals (INE, 2016), it was necessary to organize the information obtained and deducted by the various units providing health care, considering only public management.

Detailed results are available in the complete document.

The data available at INE were the comparison basis to obtain data for the project under analysis, since much of the necessary data was not available in any type of contact made. Using the Stanford case (2013), it was possible to extrapolate and estimate the obtained results, which allowed us to estimate, once again, the Stanford study (2013), the potential quantities of disposable PPE, which in practics is possible to be recycled resourcing the Thermal Compaction Group equipment. The data for each of the hospitals considered had their values between the ranges of values published by the INE.

3.1.2 Hospital Waste Management Systems

From waste stream modeling and mapping, it was possible to observe that many of the mistakes made are due to the weak screening that is currently practiced in Portuguese public hospitals. This fact can be justified by the weak training within this scope that is given to health professionals, especially those best placed in the professional hierarchy. The lack of doctors, nurses and medical assistants can also be adversely affecting the correct screening, as the workload increases for each individual, which removes availability and attention to tasks such as HW screening.

From visits to health care units, it was also found that users have considerable difficulty in sorting, repeatedly misplacing the waste in the correct deposit.

The document with the complete work shows the waste streams identified in hospitals belonging to the hospital group Lisboa Central. Among the schemes differ the departments in analysis, namely, the operating room, hospitalization units and imaging center.

3.1.3 Financial Analysis of PP recycling process

With the obtained values analysis, it was verified that the project is feasible, since it presents high TIR and VAL values. The value of the Pay-Back time ensures the viability of the project, since it is only necessary 4 years to recover the invested capital.

One of the possibilities for the implementation of this project would be the acquisition of one or more units of this equipment by WMO for the treatment and recycling process of disposable protective equipment composed of PP, composed by materials of Groups II and III.

Given that health units currently pay for the collection and treatment of HW from all the groups, the implementation of this equipment in the health units facilities could also be an added value, since in addition to the savings in the values to be paid for treatment to WMO, health units could make money from the recycling of waste, which to date has not undergone any process of re-use and recycling, but only for energy recovery. However, this scenario presents some adversities, such as the lack of knowledge that hospital managers have regarding the sale of PP bars; it would also be necessary to adapt the existing legislation to this scenario and its requirements, regulating the market and making the other actors responsible, both at the environmental and social level, taking into account that health units would not act as the WMO for all their HW. Finally, another adversity could be direct competition with current public and private HW management companies.

In view of the two scenarios described, another possibility could be an agreement between WMO s and health care units for the installation of Thermal Compaction Group equipment at the premises of the health units with the largest production of disposables in Groups II and III constituted by PP. Between the two entities an agreement would be reached, where the responsibilities and rights of each party would be present, reducing the HW management costs of the health units and giving other sources of income to the WMO.

4 Conclusions

With the laboratory work development, it was possible to verify that practically all disposable PPE gently delivered by health care units have high HCV values, that corresponds to the PP polymer. This fact indicates that its composition is mainly of PP. It should also be noted that regardless of the manufacturer, the material is uniform in its constitution, which does not impose any objection to the recycling of disposable PPE according to the Thermal Compaction Group methodology.

It should be emphasized that the recollecting of data for the development of the presented work was frankly difficult and was only possible due to a couple of manners, through direct contact with the most varied health professionals, and from data collected in platforms, such as INE, together with international studies already carried out, which allowed to make assumptions. Adding to this gap, there still is an absence of scientific studies within the scope of recycling of PPE from NWF in a hospital setting.

However, this technique has low operating costs, and the equipment can be installed in healthcare units, reducing the transport costs associated with HW. From the financial analysis carried out, where a real scenario was considered, that is, social security spending were take into account, a market growth of 3% per year and a 20% decrease in the value of the HW treatment compared to the current value.

Regarding the project, it should be noted that its feasibility is high, as it is the pertinence. If any entity is willing to place this project in question, the initial financial amounts will not exceed 100,000 € and they'll have a financial return within 4 years. This solution will still solve a Portuguese problem, since currently all HW from Portuguese hospitals go to sanitary landfill or incineration with energy recovery, with a high collection and treatment costs, which translates into a high financial burden for the healthcare units, whose investments and funds have to be well managed and directed.

It should also be noted that the estimated annual production figured for the various hospital units showed that there is sufficient residue to reach the maximum efficiency values of the equipment, and in some units the high PPE disposable composed by PP consumption values. Examples are the hospitals of Santa Maria, São José and Curry Cabral.

Finally, with the waste flow mapping it was possible to understand that currently HW is poorly sorted. However, for this scenario to improve, it is imperative to invest in training and sensitization of health professionals and other users.

Still within the used materials, some disposable equipment have a product design that does not conform to the specifics attributed to them in matters of life ending, for example, some equipment are made up of materials that give a considerable weight, which interferes in the costs charged for the treatment of that same HW because the value is charged per kg of waste. Therefore, these types of articles should be reviewed, as well as their constituents and design. The solution may also be to revise the legislation and create an exception that allows for the budgeting of these articles differently, considering, for example, the volume they occupy.

4.1 FUTURE WORK

In the process of the performed work there were some shortcomings regarding information and studies developed in the scope of HW management, focusing on disposable PPE composed by PP. One of the suggestions is the creation of a governmental database, with information on disposable PPE consumption, as well as the final destination that is attributed to them (recycling, incineration, landfill, etc.).

It would also be interesting to carry out a life cycle analysis on carton containers for HW collection and then compare it to the life cycle analysis of reusable containers in order to propose the best decision based on the same analysis.

Also within the scope of life cycle analysis (LCA), it may be essential to conduct a review of disposable PPE resulting from recycled material and compare it to the PPE's LCA without considering its recycling, as well as to the LCA of reusable protection equipment such as the white coats. From these comparisons, the appropriate conclusions should be drawn when considering the financial, environmental and material viability over time.

Regarding this specific project, it is suggested to review the legislative framework in order to understand if the current Portuguese legislation is prepared to regulate and license NWF recycling equipment installed in health care units. In this analysis, in addition to the licensing values and the documents needed for the process, it would also be interesting to assess the time that the licensing process would take, in order to see if the reality is in line with the real needs of the national producers and WMOs.

Still within the project presented, if there is interest in the implementation of this system, it will be necessary to understand which agreement between hospital units and WMOs is more beneficial and profitable for both parties.

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