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Packaging design in the healthcare field: eco-guidelines for sustainable packaging and disposables in dialysis treatments

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Abstract

The recent economic crisis has emphasized the costs for diagnostic and therapeutic procedures. Resource consumption and waste production are huge environmental problems, but they also represent a significant cost for National Healthcare Services. The analysis of scientific literature showed a great potential in the field of environmental sustainability that is currently addressing political and educational research. Design could improve environmental and economical sustainability of medical treatments, creating new products and systems able to optimize resource consumption and reduce waste. The collaboration between designers and nephrologists brings together interdisciplinary skills to jointly face the research problem, focusing on chronic haemodialysis. This treatment exerts a high environmental impact, because of the need of a huge quantity of disposables, resulting in a great amount of waste for each treatment. All disposables and packaging used in different dialysis treatment methods were classified and analysed to define the main issues and potentials. A specific qualitative-quantitative methodology was implemented, starting from the disassembly of product components. Functional and environmental problems were identified for each category and specific guidelines outlined. These provided practical design indications, not only concerning sustainability requirements, but also functionality and communication. The application of guidelines could make it possible to improve the environmental and economical sustainability of packaging and disposables for haemodialysis treatments.

Keywords: packaging, dialysis, interdisciplinary research, design methodology, guidelines

Introduction

The recent economic downturn has had a huge weight on the healthcare sector in terms of tightening spending and reductions of expenditures for diagnostic and therapeutic procedures. The cutbacks of NHSs (National Healthcare Services) have involved the whole healthcare supply chain. The majority of supply chain decision makers still feels the impact of economic recession (54% in North America and 43% in Western Europe) or considers the impacts have lessened but are still present (44% in North America and 49% in Western Europe) (TNS, 2014). The work of Clemens *et al* (2014) highlights how European NHSs addressed the crisis through short-term measures to control costs, but long-term improvements are still needed to guarantee economic sustainability.

In this scenario, many environmental issues are arousing interest since they also represent a significant expenditure for NHSs (Evans, Hills and Orme, 2012). Resource consumption and waste production have huge environmental impacts and deeply affect the costs of many medical treatments. The analysis of scientific literature showed that much research in recent years has focused on education and policy studies to face these issues. The main solutions recognized concern: the promotion of careful waste sorting within the hospital facilities (Grose *et al*, 2012; Vogt and Nunes, 2014); the implementation of Green Public Procurement schemes (Walker & Brammer, 2009; Oruezabala and Rico, 2012); the development of educational programmes to train staff to behave more responsibly (Richardson *et al,* 2014; Goodman and East, 2014).

Although these strategies could positively affect the long-term sustainability of healthcare facilities, they mainly focus on the downstream end of the production process. Few researchers have addressed the role of sustainable design in healthcare, and more work is needed to reach new solutions that could implement educational strategies and political actions. Design research could act upstream to improve the environmental sustainability of packaging, products and machines, in order to reduce impacts during their entire life cycle.

The purpose of this study is to address the environmental and economical issues of medical treatments from a design perspective. We especially examined the environmental burden of chronic haemodialysis, that is one of the most expensive medical treatments in terms of care expenses, resource consumption and waste production (Burnier and Martin, 2013; Connor, Mortimer and Tomson, 2010). In particular, large amounts of waste are mainly produced by disposable products and packaging (Agar, 2012; Ferraresi *et al,* 2013). Design research often deals with these aspects (Jedlicka, 2008) and can make a valuable contribution towards solving these issues.

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Methodology

Renal replacement therapy includes different methods of haemodialysis according to the patient's disease and the place of treatment (centre-based or home-based). This means using different types of machines, disposable products and packaging. In this study, three types of dialysis (and the relative machines) were chosen to carry out the analysis on waste production: 1 in-centre bicarbonate dialysis (Nikkiso), 1 ultrafiltration home dialysis (NxStage), 1 in-centre haemodiafiltration (Bellco Formula HFR). Haemodialysis treatments were simulated using saline solution as a substitute for blood, in order to avoid any risk of contamination. All waste produced during the whole treatment was analysed combining a qualitative approach with quantitative analysis. Different packaging and disposables were classified in five categories to allow comparing different dialysis methods and identifying specific problems.

The study was performed in collaboration with the SS Nephrology of San Luigi Gonzaga Hospital (Turin, Italy), and information was collected through on-the-field analysis in their Dialysis Unit (Head Physician: Giorgina Barbara Piccoli). This interdisciplinary collaboration allowed bringing together complementary skills in order to detect all critical points and determine a set of guidelines for designing more sustainable solutions.

Packaging and disposables categories

Packaging and disposables were first reported and divided in five categories, according to the product/packaging function in the treatment. This was essential to establish a common language between different disciplines and avoid any ambiguity in relation to the terminology.

The first two categories concern products that are commonly described as "packaging":

1. *Packaging for transport* is a secondary packaging allowing the transportation and the storage of primary packaging and products. It is thrown away as urban waste (e.g. cardboard boxes).

2. *Packaging for distribution* is a primary packaging allowing transportation and handling of the product until the use phase. It is discharged just after being open and can be usually disposed as urban waste (e.g. plastic films).

The third category includes devices that are essential for the treatment but, in the design field, can be defined as "packaging" because they contain the product itself (usually liquid solutions):

3. *Packaging for treatment* is a primary packaging allowing the transportation, handling and use of the product. It is connected with medical equipment in order to use the product it contains. It must with biocompatibility standards but can be disposed as urban waste (e.g. saline solution bag).

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The fourth and fifth categories cover medical devices with a different degree of complexity:

4. *Disposables* are one-use products for medication (e.g. gauzes) and therapeutic procedures (e.g. fistula needles). Disposables must meet biocompatibility requirements and functional effectiveness. They are usually considered hazardous waste.

5. *Biomedical devices* are key products of the dialysis treatment. They need to comply with high level of biocompatibility and technical requirements. They are usually disposable and regarded as hazardous waste (e.g. dialyzer).

In this work, biomedical devices were not considered because they present a high complexity that should be analysed in close connection with the machine. Future work will address the design of dialysis equipment and biomedical devices.

Quantitative analysis

The quantitative analysis of packaging and disposables has mainly concerned weights and materials, since they are huge issues both from the point of view of environmental and economical impacts (Agar, 2013). Indeed, the type and weight of waste deeply affect the potential for recycling, resource consumption (within production and transportation phases) and the cost of waste disposal. All waste produced during the whole treatment was collected and weighted using an electronic weighing scale. In many cases packaging for treatment contained residual non-contaminated fluids (e.g. saline solution). Even though many packaging could not be emptied, we force emptying by means of cutting tools to verify the potential weight reduction.

Another important aspect to consider is the contamination of waste after the treatment, as it impacts the cost and the potential for recycling. We identified the contaminated items (hazardous waste) and the non-contaminated ones (urban-type waste). That is important to understand which packaging/disposables can be redesigned to facilitate recycling and which ones have to be immediately discarded.

Then, we reported all materials to verify which are the most used and which might affect waste recycling. In particular some composite materials and polymers (e.g. PVC) need specific a recycling process (Carvalho, 2012) and they often show a low recyclability level (Sadat-Shojai and Bakhshandeh, 2011). This allowed us to provide indications about the choice of more sustainable materials.

Finally, the economic assessment of current waste production was performed, according to the minimum and maximum cost of disposal in Piedmont Region - Italy (where the reference Dialysis Unit is located). In addition, two different practices of waste sorting were considered, because a careful separation of waste could deeply affect the cost of disposal:

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- *careful practice*: hazardous waste is separated from non-hazardous waste, taking special care and carefully emptying all the residual fluids from the disposables;
- *careless practice*: no waste is emptied and different components are not differentiated.

The quantitative analysis involved disposables and primary packaging only, because secondary packaging (mainly cardboard boxes) cannot be referred to only one dialysis session or machine. However, they were considered in the qualitative analysis to determine the main design issues.

Qualitative analysis

Quantitative analysis is significant but not sufficient to determine all the problems in packaging and disposables design. So a qualitative analysis was performed, based on the Environmental Sustainability Analysis method, which has been developed since 2005 by the Department of Architecture and Design at Politecnico di Torino (Barbero, Pereno and Tamborrini, 2011). This method allows comparing the quantitative features of packaging and disposables (weight, materials, volume) and the qualitative ones (figure 1). In particular, each product is disassembled and evaluated according to common criteria:

- *Functionality*: optimization of storage and volumes; efficiency of preservation and protection; usability (handling, opening/closing).
- *Sustainability*: use of over-packaging; easiness of disassembly (joints, material composition); volume optimization (ratio between packaging and product).
- *Communication*: operating information; waste sorting information; use of standard labels and eco-labels; communication effectiveness.

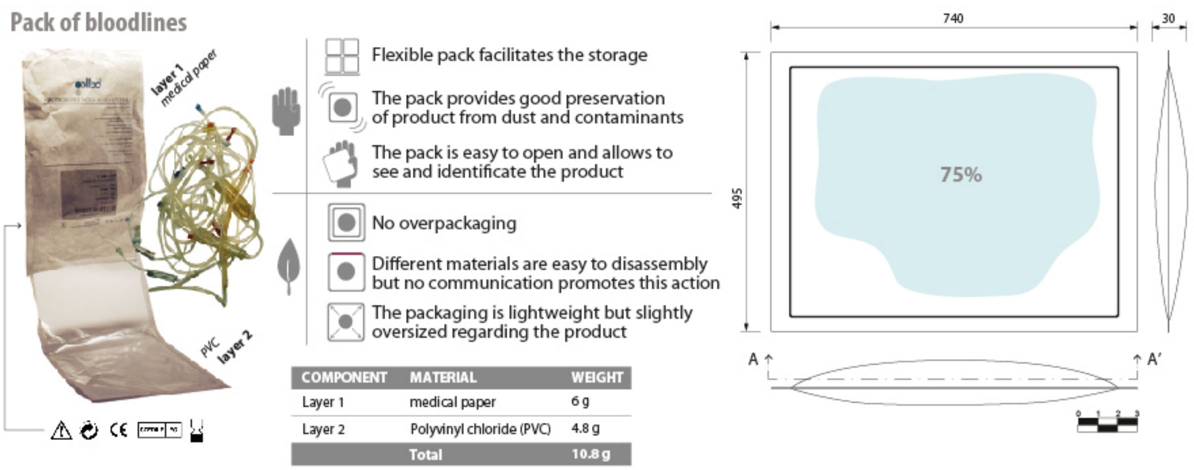

Figure 1: Example of Environmental Sustainability Analysis applied to the packaging of bloodlines

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All packaging and disposables were individually assessed and the results were summarized according to the main qualitative features: packaging-product weight ratio; packaging-product volume ratio; material composition; easiness of disassembly; fastening type; use of adhesives; labelling; information.

Results

In this work, we sought to establish a methodology for the analysis of waste issue in medical treatments in order to provide a set of guidelines for designing more sustainable packaging and disposables. On the whole, quantitative analysis showed many problems concerning the weight of packaging for treatment and the use of materials difficult to recycle. On the other hand, qualitative analysis highlighted difficulties in the disassembly of different materials, a general oversizing and the lack of information for promoting recycle. The interpretation of these issues, partly thanks to onsite observations, allowed us to define eight main design guidelines for packaging and disposables.

Quantitative results

The overall results of weight and economic analysis are reported in table 1. Weights of different product categories are indicated according to "careful" and "careless" practices, as mentioned in the methodology section. The first issue is the overall amount of waste produced in each dialysis session, which may be up to 5 kilogrammes approx. If we consider that each patient makes at least 3 sessions per week, the waste production is from 120 kg to 780 kg per patient per year. This issue is deeply affected by the emptying of waste from residual fluids, as detailed in Table 1: the weight of non-emptied contaminated waste can increase by 60% (home dialysis) to 150% (in-centre bicarbonate dialysis), while the weight of non-emptied and non-contaminated waste can increase by 373% (home dialysis) to 549% (in-centre bicarbonate dialysis). This is also a huge problem from the economic point of view, as the cost for waste disposal can rise by 83% to 177%.

Table 1. Weight of dialysis waste according to different dialysis methods and waste sorting practices

	In-Centre Bicarbonate Dialysis		**In-Centre Haemodiafiltration**		**Home Ultrafiltration dialysis**	
	Careful	Careless	Careful	Careless	Careful	Careless
Pack for distribution	92,60	92,60	128,20	128,20	169,90	169,90
Pack for treatment	729,60	6830,10	679,50	5580,10	575,10	3365,00
Disposables	132,90	132,90	132,90	132,90	132,90	132,90

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Biomedical Devices	1000,00	1050,00	1750,00	1850,00	700,00	1200,00
TOTAL WEIGHT (g)	1955,10	8105,60	2690,60	7691,20	1577,90	4867,80
Contaminated Waste (TOT)	1165,70	2981,70	1915,70	3781,70	831,70	1331,70
Non-contaminated Waste (TOT)	789,40	5123,90	774,90	3909,50	746,20	3536,10
MEDIUM COST (€)	3,9	10,7	6,2	12,9	2,8	5,1
Minimum Cost	1,0	3,3	1,5	3,5	0,7	1,8
Maximum Cost	6,7	18,1	10,9	22,2	4,9	8,4

Moreover, the analysis of materials highlighted that the 47% (in weight) of non-contaminated waste (i.e. pack for treatment and pack for distribution) is made from composite polymers, which are composed of two or more layers of plastics and are difficult to recycle. Packaging made from one material or easily separable materials account respectively for 21% and 32% of the total.

Overall, design should address the possibility of emptying packaging/disposables after the haemodialysis session, as well as the importance of investigating alternatives to the use of composite materials and/or communicate the proper sorting of different components.

Qualitative results

The qualitative comparison confirmed that the main problems are not related to the dialysis method or machine, but to the type of product. Figure 2 illustrates the qualitative findings divided in functional and environmental issues; for each issue the relative category of packaging/disposables is indicated.

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FUNCTIONAL ISSUES		ENVIRONMENTAL ISSUES
> Difficulties in **handling heavy-weight packaging** with no gripping points. > **Top opening systems** are not comfortable to take the items contained within the pack.	PACK FOR TRANSPORT	> Use of **oversized packaging.** > Very **short life** and no possibility to reuse.
> **Oversized packaging** does not optimize the storage phase.	PACK FOR DISTRIBUTION	> AVF Connection Kits include many **disposables that have to be discarded** even if they were not used. > Use of **oversized packaging.** > **Difficulties in disassembly** different components. > **Little information** about the disposal (materials, waste sorting, etc.) > Very **short life** and no possibility to reuse.
> Difficulties in **handling bulky flexible packaging.**	PACK FOR TREATMENT	> **Difficulties in emptying pack** from residual materials (Bicarbonate Cartridge) or fluids (Flexible bags). > **Use of composite polymers** constituted by layers that are not individually separable. > **Little information** about the disposal (materials, waste sorting, etc.). > Very **short life** and no possibility to reuse.
> Difficulties in the disposal operations of **bulky hazardous waste.**	DISPOSABLES	> Pre-assembled kit for Home Hemodialysis does not allow to **disassembly different components.** > **Little information** about the disposal (materials, waste sorting, etc.). > Very **short life** and no possibility to reuse.

Figure 2: Main functional and environmental issues of dialysis packaging and disposables.

The qualitative issues confirmed the quantitative results, expanding them with the aim of exploring the problems from a design perspective. Starting from these final results, we sought to establish a set of design guidelines.

Design guidelines

Design guidelines combine quantitative and qualitative results to provide practical guidance for designing more sustainable packaging and disposables for dialysis treatments. Environmental sustainability is closely related to functionality, since a sustainable packaging should first reach the goal for which it has been designed. Then, we defined functionality and sustainability guidelines, in order to effectively respond to the design needs.

Although the study focused on packaging and disposables, many issues should be addressed involving the equipment and/or the whole treatment. In many cases environmental sustainability can only be achieved through the coordinated design of different elements. Therefore, for each

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guideline has been define the category involved, and if the project should be extended to the machine or the whole treatment (additional products; space design; behaviours etc.).

Functionality guidelines (figure 3) mainly address the treatment management by facilitating the supply of all the disposables for each dialysis session (improving packaging for transport), and the set up phase, especially in home haemodialysis.

FUNCTIONALITY GUIDELINES		PACK/DISPOS.	MACHINE	TREATMENT
	**Improve movement and handling of secondary packaging** *Design secondary pack providing gripping points and facilitating the opening even when stacked.*	● Pack for Transport		●
	**Facilitate the set up phase both for HHD and IHD treatments** *Avoid the use of pre-assembled kit, designing new systems easy to use even by non-medical staff for HHD treatments.*	● Pack for Treat Disposables	●	●
	**Facilitate the end of dialysis phase and the sorting of hazardous waste** *Improve the disposal operations of bulky hazardous waste (bloodlines/dialyzer/infusion line).*	● Pack for Treat Disposables		●

Figure 3: Functionality guidelines

Sustainability guidelines (figure 4) address the specific and general issues that most impact on resource consumption and waste production. Optimization of resources can be pursued by: enhancing the supply personalization for each dialysis session (optimizing medical kits); avoiding standard oversized packaging; extending the lifecycle of secondary packaging. Waste production can be reduced or optimized through: the design of packaging and disposables that could be emptied; the possibility of disassembly different components; the communication of proper disposal operations.

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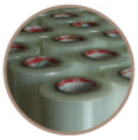
SUSTAINABILITY GUIDELINES		PACK/DISPOS.	MACHINE	TREATMENT
	**Design the composition of AVF connection kits** *Avoid the waste of not used products and/or allow the personalization of the kit according to the specific treatment method.*	● Pack for Distr. Disposables		●
	**Optimize packaging dimensions** *Avoid unnecessary oversizing, especially in secondary packaging.*	● Pack for Distr. Pack for Transport		
	**Extend the lifecycle of secondary packaging** *Evaluate the use of reusable secondary pack or provide added functions.*	● Pack for Transport		●
	**Allow the emptying of residual materials** *In particular the bicarbonate contained in the bicarbonated cartridge and the solution residuals in flexible bags.*	● Pack for Treat	●	●
	**Allow the sorting of different materials** *Avoid permanent joints and, if possible, the use of composite materials and composite polymers.*	● Pack for Treat Pack for Distr.	●	
	**Improve the communication of the disposal** *Provide information about materials, processes to facilitate recycling and waste sorting.*	● Disposables Pack for Treat. Pack for Distr.		

Figure 4: Sustainability guidelines

Conclusions

The healthcare sector is suffering from significant spending cuts that in many cases affect diagnostic and therapeutic procedures. On the other hand, widespread awareness about the importance of environmental sustainability is also relevant to the medical field. In particular, major environmental issues cuh as resource consumption and waste production are arousing interest since they also represent a striking cost for healthcare facilities.

Much study in recent years has investigated the environmental impacts of medical treatments and systems (Evans, Hills and Orme, 2012), identifying possible solutions that mainly address educational programmes, supply policies and disposal logistics.

This study differs from the previous research, aiming to face the challenge of environmental and economical sustainability from a design perspective. Our current findings expand prior work in the

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haemodialysis field (Agar, 2012) to settle upstream problems by the role of design towards sustainable healthcare.

Our results provide a clear definition of the main issues to solve in order to improve sustainability. The analysis was not limited only to indicate the problems, but it provided a solid basis of guidelines for further design projects. Furthermore, the presented methodology could be applied to a wide range of medical treatments for identifying problems and proposing solutions.

These promising results should be verified in future practical applications: in the short term, further work should focus on the design of sustainable packaging and disposables to assess the actual savings in term of material used and waste reduction. However, in the medium-long term a comprehensive design of the medical system as a whole is needed. The combination of packaging, disposables, biomedical devices, and equipment could create a sustainable towards the promotion of environmental, social and economical sustainability.

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