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Medical waste management: a case study in a small size hospital of central Italy

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Abstract

Purpose – A measurement campaign was carried out for assessing the waste flow in a pilot hospital of a region in central Italy, with the purpose of having a complete overview of the waste stream and of the personnel behavior in managing and handling waste flow both internally and in outsourcing. The main aim of the work was to provide instruction for decreasing waste quantities, improving segregation and decreasing costs and environmental risks. Moreover an analysis of the effectiveness of outsourcing the waste management service in terms of cost reduction and efficiency improvements and of the limits has been performed.

Design/methodology/approach – A self-assessment model was proposed for evaluating waste generation patterns, quantities and sources and identifying anomalies. The research team comprised the hospital administrator, the head physician and charge nurse of each hospital ward, the administrative in charge of the waste management documents, the head of the hospital pharmacy, the responsible for the external outsourcing company in charge of waste collection and disposal, and the research team of Università Politecnica delle Marche. The data were obtained through the questionnaires elaborated by the group and submitted to a selected sample of personnel; they were asked to provide information on waste management practices (generation, collection, segregation, cleaning, storage) and quantities.

Findings – Anomalous behaviors were identified in the high amount of solid waste going into the medical waste stream; corrective actions have been proposed and their effectiveness has been monitored after implementation. The measures allowed a reduction of medical waste from 13 to 15 percent in two analyzed wards with a significant reduction of waste management costs.

Originality/value – This work has been requested and supported by the management of the healthcare structure analyzed, and represents a first step in the implementation of a policy that considers waste management as one of the fundamental processes for the proper functioning of the hospital.

Keywords Benefits and financial results, Knowledge management, Localisation issues, Modelling (of systems and processes), Performance management, Benchmarking

Paper type Case study

1. Introduction

Medical waste management represents one of the main issues for healthcare structures and public government bodies both for the costs and for the environmental impact and risks associated; moreover they have the need to ensure compliance with the laws governing medical waste.

Medical waste is all waste materials generated at health care facilities and includes any solid waste that comes from the diagnosis, treatment, or immunization of human beings or animals, in research or in the production or testing of biologicals. This definition includes, but is not limited to:

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- blood-soaked bandages;
- culture dishes and other glassware;
- discarded surgical gloves;
- discarded surgical instruments;
- discarded needles used to give shots or draw blood (e.g., medical sharps);
- cultures, stocks, swabs used to inoculate cultures;
- removed body organs (e.g., tonsils, appendices, limbs); and
- discarded lancets.

Between 75 percent and 90 percent of the waste produced by health-care providers is non-risk or general health-care waste, comparable to domestic waste.

It comes mostly from the administrative and housekeeping functions of health-care establishments and may also include waste generated during maintenance of health-care premises. The remaining 10-25 percent of healthcare waste is regarded as hazardous and may create a variety of health risks.

Preventing the formation of medical waste, gives a significant contribution to the reduction of waste management expenses in healthcare. The cost to handle and dispose of medical waste is indeed substantially more than solid waste handling. This makes efforts to reduce commingling of these wastes a worthwhile task. When solid waste is mixed with medical waste it must be treated as part of the medical waste stream which handling costs about 20 times more that solid waste.

Moreover, in recent years too many cases of medical waste being improperly stored or disposed has been discovered in Italy. There are many reasons at the origin of this problem and different responsible such as negligence and/or poor qualification of personnel in charge of the segregation and disposal in the healthcare structures; lack of strategies and plans for a correct and effective handling of medical waste; negligence and/or illegal behavior of medical waste collection transportation and treatment companies. The damages correlated to such situations are very high since the wrong management can cause environmental pollution and risks for the citizens' health.

Beside the above-mentioned risks, it is important to consider also aspects related to the great amount of waste generated in the healthcare structures and the high costs for handling such quantities; moreover, the possibility that conflicts of interest arise from the outsourcing of the service, has to be taken into account.

The first step in order to manage in a cost-effective way the waste stream is to be able to assess the flow in all its aspects: generation, handling, transportation and treatments through the entire structure.

The waste produced in healthcare can be divided in four main classes:

(1) hazardous and infectious waste that might contain pathogens, like bloody gloves or used hypodermic needles (HMW-I);

(2) hazardous waste that can cause injury without infection, such as needle pokes (HMW);

(3) non-hazardous waste such as non-dangerous chemicals and drugs (MW); and

(4) general solid waste (GSW) comparable to domestic waste.

The study proposes a self-assessment method for decreasing the amount of waste produced and optimizing its differentiation; in particular it focuses on the correct identification and segregation of Class 1 waste since it is necessary to avoid either that it may go in a different waste stream with the consequent risk for the health and environment and that solid waste belonging to Class 4 goes into the Class 1 stream with the consequent increasing of disposal costs. Moreover it analyzes the benefits and limitation related to the outsourcing of the service.

Section 3 provide an overview of the Italian situation; in section 4 the materials and methods used are discussed; section 5 is devoted to the presentation of case study and section 6 to the analysis of results and explanation of corrective actions proposed. Finally in section 7 some conclusions are drawn.

2. Literature review

Several studies have proposed the evaluation and the optimization of the medical waste; Bdour *et al.* (2007) and Fisher (2005) demonstrated in their papers that quantity of waste generated by hospitals varied by changes in local legislation. According to Tudor *et al.* (2005), the implementation of standardized and optimized management practices lead to the reduction of both infectious and general waste; their paper looks at steps taken towards the development of a ten-year strategy for the management of healthcare waste from the National Health Service (NHS) in Cornwall, UK. The major issues and challenges that affect the management of waste by the NHS, including its organizational structure and collection infrastructure, are outlined. The waste flows of the main acute medical site are detailed, using waste audits of domestic and clinical bags, redundant equipment, bulky waste, and special waste. Staff training and awareness underpin several of the short and medium/long term solutions suggested to reduce the waste at the source and recover value from that produced. These measures could potentially reduce disposal quantities by as much as 20-30 percent (wt.) and costs by around 25-35 percent.

Today, the healthcare facilities are under severe stress due to the huge population they are required to support. This has led to an exponential increase in the amount of waste generated in hospitals. Improper disposal of wastes in hospitals places direct and indirect health impacts on those working in hospitals and the surrounding communities and on the environment. Thus, collection, transportation and disposal of hospital waste have turned into a complicated and critical problem. Since there are several barriers to the implementation of an effective hospital waste management program, an effort has been made in this paper to understand the mutual relationship among these barriers, using interpretive structural modeling (Faisal *et al.*, 2010).

Cheng *et al.* (2010), investigated the type and amount of medical waste generated from small clinical facilities in Taiwan. They sampled 200 small medical establishments, with few or no patient beds, to survey the wastes generated and disposed. The surveyed medical facilities consisted of four groups including private clinics, medical laboratories, blood centers and public clinics. The overall mean general waste production rate was 3.97 kg/bed/day (or 0.075 kg/patient/day) at all the surveyed facilities, higher than that obtained from larger hospitals in Taiwan, which ranged from 2.41 to 3.26 kg/bed/day. The highest amount of infectious wastes generated among the four groups of facilities were from blood centers (3.14 kg/bed/day), followed by private clinics, medical laboratories and public clinics (1.91, 1.07, and

0.053 kg/bed/day, respectively). The overall average was 2.08 kg/bed/day. This study suggests that the waste generated at small medical facilities ranged widely.

According to Tudor *et al.* (2008), in order to decrease the amount of medical waste in healthcare investing significant resource and financial efficiencies is not sufficient. Due to the many factors involved, there is a need to focus both on containment and logistics, as well as social factors for success. In their paper they reports on the results of waste minimization trials. The schemes were able to achieve significant waste reductions in both clinical and domestic waste quantities. Indeed, a reduction in domestic bag waste in the range of 1.6-33.4 percent, with an average of 14.8 percent was realized. For clinical waste, the reduction ranged from 1.8 percent to 38.3 percent, at an average of 15.7 percent, with net cost benefits of nearly US$ 25,000 over the period of one to three years.

Insa and Zamorano (2010) presented a critical review of medical waste legislation in Spain. They proposed a set of general criteria on which medical waste management should be based: a clear definition of medical waste and of the scope of legislation concerning it; basic principles to promote the reduction of the amount of waste generated at a source; a homogeneous classification of this waste; and the implementation of environment-friendly waste treatment technologies.

The problem of medical waste management is even more critical in developing countries and it has been addressed by a few scientists in the past years.

Moazzam and Chushi (2009) demonstrated that healthcare waste management is a serious public health concern, in developing countries, in which, compared with developed nations, the management of infectious wastes has not received sufficient attention. Recently, worldwide awareness has grown of the need to impose stricter controls on the handling and disposal of wastes generated by healthcare facilities. In their paper they proposed an overview of handling practices, occupational safety, and the implementation status of waste management policy, together with other pertinent policy issues, in seven selected hospitals.

Alhumoud and Alhumoud (2007) analyzed the amount of different kinds of solid wastes produced, segregated, collected, stored, transported and disposed of in the governmental hospitals of Kuwait. The weight fraction of each component in the sorting sample was calculated by the weights of the components. The amount of non-infectious and infectious waste generated in kg/day in each ward and various hospital blocks were determined and recorded. They assessed the risks associated with the lack of training courses on waste management in the analyzed hospitals.

Lee *et al.* (2004) in their paper identified measures for the effective waste characterization methods for the reduction of treatment and disposal costs of regulated medical waste.

There are also many works dealing with the outsourcing phenomena in healthcare but not specifically related to the medical waste management. According to Brown and Wilson (2005), healthcare sector is pointed as one of top three sectors (along with Finance and Legal) having a higher outsourcing growth. Macinati (2008), in her paper reported a national survey on the outsourcing in the Italian National Health Service; Guimarães and Carvalho (2010), presented a detailed reviews of the state of the art literature on outsourcing in healthcare sector and gives a structured frame of outsourcing in different countries with different health systems. Billi *et al.* (2004)presented a model for the strategic outsourcing of clinical services. Fattore

(1999) investigated on cost containment in the Italian National Health Service addressing also the impact of outsourcing. Many researchers dealt with A series of guidelines for implementing strategic outsourcing decisions are reported in Jennings (1997) and Roberts (2001); meanwhile the hidden costs of outsourcing strategies were discussed by Hendry (1995).

3. The Italian situation

Healthcare waste management, including hazardous waste, in Italy is regulated by DPR 254/2003, "Regulation for medical waste management in accordance with Law n. 179 of July 31, 2002, art. 24" and by Ministerial decree 26/6/00, n. 219 in order to avoid risks for human health and environment.

The last technical report on the medical waste situation in Italy was produced by APAT in 2008 reporting data acquired on an observation period of four years.

The healthcare structures present in Italy are about 1,300, of which 60 percent are public structures and 40 percent private (accredited from the Health Minister); with a number of beds of about 217,000 (including day hospital) for the public and of about 54,000 for the private accredited structures.

The results of the analysis outlined an increasing of the medical waste production that from 136.606 tons in the first year of the observation reach 142.451 in 2008.

Also the percentage of hazardous waste, with respect to the total amount of medical waste, has increased going from 90,6 percent to 94,8 percent in the same period.

Five regions over 21 (Lombardia, Lazio, Emilia Romagna, Veneto e Piemonte) produce more than 50 percent of the total medical waste in Italy. The majority of medical waste comes from healthcare structures (in particular public and private hospitals).

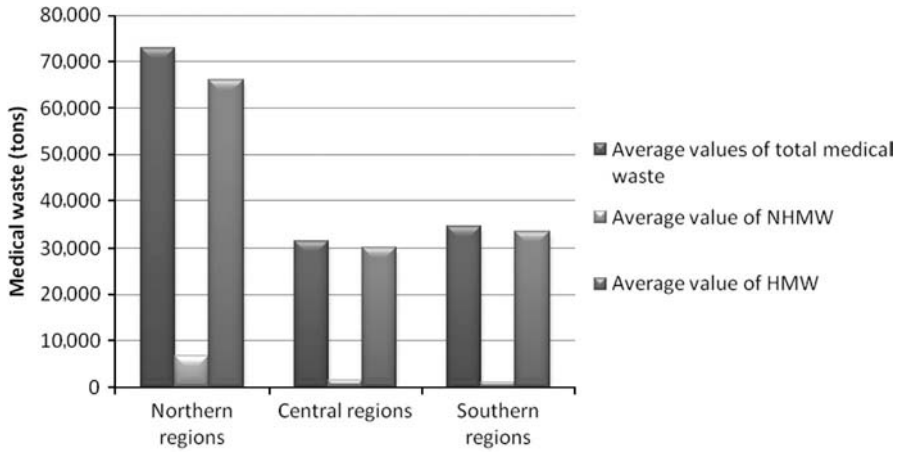
The annual production per capita, in the considered period, has registered an average value of 2.3-2.5 kg/inhabitant*year. At regional level, from the study it has been demonstrated a strict correlation between medical waste produced and number of inhabitants.

In Table I and Figure 1 is reported the total amount of waste produced in Italian healthcare structures divided in three main territorial areas (northern regions: Piemonte, Valle d'Aosta, Lombardia, Trentino Alto Adige, Veneto, Friuli Venezia Giulia, Liguria, Emilia Romagna; central regions: Toscana, Umbria, Marche, Lazio; southern regions: Abruzzo, Molise, Campania, Puglia, Basilicata, Calabria, Sicilia, Sardegna) during the four year observation period (APAT, 2008).

As for the management of sanitary waste it has been demonstrated that Italy represents one of the most frequently outsourced general services with a percentage of 80 percent (Macinati, 2008).

Table I. Average quantities of MW produced in Italian regions in a four-year period

	Average value of total amount of MW produced (tons)	Average value of total amount of NHMW produced (tons)	Average value of total amount of HMW produced (tons)	Percentage of NHMW on total MW	Percentage of HMW on total MW
Northern regions	72,842	6,697	66,145	9.2	90.8
Central regions	31,508	1,510	29,998	4.8	95.2
Southern regions	34,685	1,113	33,572	3.2	96.8



Notes: NHMW-Non Hazardous Medical Waste; HMW-Hazardous Medical Waste

Figure 1.
Medical waste produced in the Italian regions

The report outlined also that the medical specialties that have the higher impact on medical waste production are:

- infectious disease with an amount of about 2.5-2.8 kg/bed*day;
- surgery (different specializations), from 1.8-2.1 kg/bed*day;
- oncology (different specializations), from 1.5-2.7 kg/bed*day; and
- orthopedic and traumatology, from 1.3-1.5 kg/bed*day.

The fees usually applied by the companies operating in the sector of medical waste disposal depend on the category of waste; the list reported below represents the average reference costs in Italy:

- hazardous and infectious waste: 0.60-1.20 €/kg;
- out-dated pharmaceutical waste: 0.90-1.10 €/kg;
- chemicals and laboratory substances: 0.30-0.50 €/kg; and
- other hazardous chemicals 0.90-1.00 €/kg.

The analysis of data acquired in the four-year period shows that the average unitary cost for the disposal of hazardous medical waste (calculated as national average), increases from 0.893−€/kg to 0.932−€/kg. Considering the hazardous infectious medical waste, the same value goes from 1.128−€/kg to 1.172 €/kg.

A sample of 185 public Italian healthcare structures over the 325 present were chosen for assessing the costs in the different Italian regions. In Table II and Figure 2, are reported the average quantities of hazardous medical waste (HMW), non-hazardous medical waste (NHMW) and hazardous infectious medical waste (HMW-I) calculated in the 185 sample structures of three territorial areas. In the northern, central and southern regions were analyzed respectively 93, 34 and 54 healthcare structures.

4. Material and methods

An effective medical waste management plan must have as its first priority compliance with the laws governing medical waste. Moreover it should focus on the following benefits:

- environmental impact reduction due to waste minimization, correct segregation of material, reduction of contamination risks;
- costs saving due to an effective waste management and minimization actions; and
- technical feasibility of plan implementation.

4.1 Medical waste optimization plan (MWOP)

The proposed model has the aim of improving the medical waste management by identifying and addressing all issues (economic and environmental) and non-compliances with the regulation and the structure policy.

The waste stream has to be flowcharted through the entire facility in order to identify all the generation sources, the relative waste typology and quantities, and their movements. A questionnaire have to be elaborated and submitted to all personnel involved in medical waste management and handling and to the outsourced company in charge of the waste collection and disposal.

Italian regions	Average HMW (tons)	Average HMW + NHMW (tons)	Average HMW + HMW-I (tons)	Average costs (€)
Northern regions 93 structures	37,081	39,942	50,458	36,557
Central regions 34 structures	12,960	13,399	14,614	17,608
Southern regions 54 structures	17,118	17,525	19,210	22,762

Table II.
Average quantities and costs of different class of medical waste in Italian regions

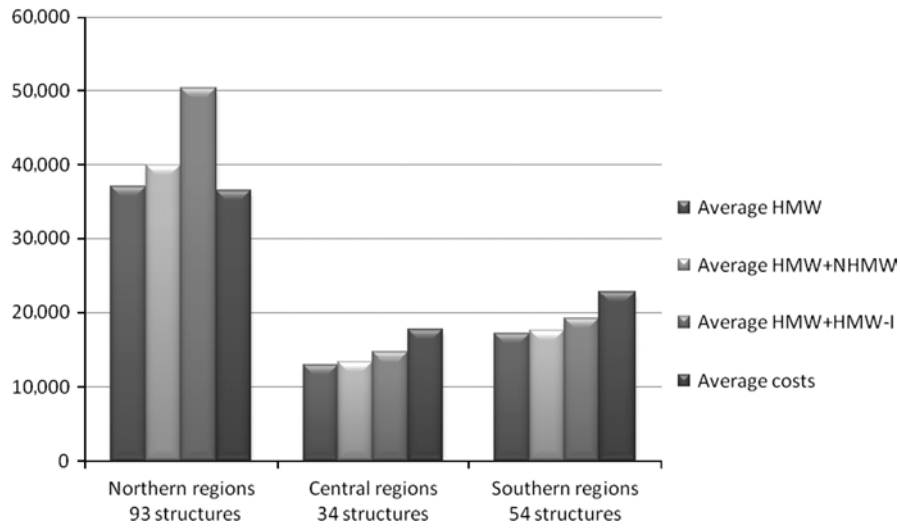


Figure 2.
Scheme of the average quantities and costs of different class of medical waste in Italian regions

This first analysis will allow us to obtain a complete and detailed picture of the actual medical waste management plan.

The next step will be to study each single process and detect any issue or non-compliance with the regulation and the environmental corporate policy. In this phase also the cost effectiveness of the current practices will be evaluated.

Finally guidelines and procedure for eliminating non compliances, decreasing associated risks for health and environment and decreasing waste management costs will be elaborated

4.1.1 Phase 1: medical waste stream assessment (MWSA). The first step of the optimization plan consists in the assessment of the current waste stream by implementing a survey evaluating types and quantities of waste generated in healthcare structures. The main aims of the survey are:

- detailed knowledge of waste types and related quantities;
- identification of all the waste generation sources for each type of waste; and
- assessment of applied disposal methods.

Beside determining the volume of medical waste being generated in a defined time period, it is necessary to understand the processes and steps that the medical waste goes through from the point of generation to the final disposal for understanding how and where the waste is handled and stored

The actions that are needed in order to reach a deep level of knowledge of the flow are the following:

- characterization of all the waste sources (medical waste generation data from the various units within the health care facility should be recorded using for example Pareto graph);
- identification of all the waste type;
- identification of the associated containers and storage method;
- identification of waste management responsible for the single wards and for the entire structure;
- location of the waste storage sites in the single wards (interim storage site);
- tracking of the waste movements and of the transportation means through the facility;
- characterization of final storage location;
- identification of on-site treatments (if present); and
- identification of disposal companies.

4.1.2 Phase 2: medical waste stream handling (MWSH). In this phase a critical analysis along the path the medical waste has traveled from its point of generation will be performed; the following topics will be addressed:

- waste segregation practices (cases of medical waste being erroneously placed in the solid waste stream should be detected and tabulated by location where the violation occurred);
- personnel awareness toward the problem of waste management optimization and risk associated;

- personnel training on medical waste handling procedures and segregation practices;
- human resources needed for handling the medical waste stream (the amount of resources should be calculated at the various points where the waste is stored, transported, and treated);
- costs effectiveness of current medical waste handling (different options such as on-site versus off-site treatments should be evaluated);
- compliance of the actual system and of the outsourcing company with the policy of the analyzed healthcare structure related to sustainable management of resources and reduction of risks for environment and health; and
- capability to adapt to future need of the structure.

The main aim of this phase is to identify areas where process improvement projects should be initiated and is to provide instructions for solving the identified issues ensuring that the waste management plan is capable of handling in an effective manner the varied components of the waste stream, to achieve cost efficiencies, to guarantee worker safety, use, and lastly, public and environmental health protection.

4.1.3 Phase 3: medical waste stream minimization (MWSM). Beside the assessment of the current waste stream management, handling and related issues a waste minimization campaign should be undertaken.

To be effective waste minimization efforts should be promoted by the management and begin with a detailed formulation of implementation strategies.

Management should promote personnel training and awareness, communicate in a clear and effective manner the objectives of the campaign, involve external companies in charge of waste collection and disposal in the plan.

The minimization strategy should also introduce the following actions:

- waste tracking mechanism (daily, weekly or monthly);
- periodic reports on the obtained results;
- periodic training sessions for staff involved in waste handling;
- constitution of a working group for coordinating the waste minimization actions; and
- involvement of the outsourced service company.

Starting from the knowledge of the type, sources and relative quantities of the medical waste stream (for example using the Pareto analysis carried out in phase 1), a production trends for each category (on a defined time period) should be elaborated to identify highest waste generation areas, abnormal behaviors and generation patterns; moreover a comparison between parameters such as kg/day/bed or kg/patient/day, with other healthcare structures should be made with the objective of implementing a series of measure to reduce the total amount produced.

There are two different and complementary methods that can be used for reducing the amount of medical waste:

(1) *Upstream method: suppliers involvement*. A purchasing strategy should include the objective of minimizing either medical waste or associated waste (packaging, food, consumables in general). The strategy includes the

optimization of the procurement through a more precise evaluation of the healthcare structure needs and the reduction, where possible of drugs, reagents, and medical item in general. The purchasing mechanism can also be an effective way to introduce the use of products with a lower environmental impact in the health care, thus incorporating the concept of environmental performance in the definition of the quality to the healthcare sector.

(2) *Downstream method: waste management*. An effective management of the reverse flow in healthcare facilities means developing a suitable waste management model. This includes the preliminary identification of the waste stream and its sources, the implementation of good practices for reusing and recycling when possible, training programs to evaluate the risks of a wrong management and the related increase of costs, and the involvement of outsourcing company for introducing recyclable containers and materials wherever possible.

The main actions can be synthesized in the following list:

- Prevention: elimination and reduction of medical waste sources (e.g. eliminating solid wastes from the medical waste stream).
- Reduction: reduction of the amount generated by each source.
- Segregation: correct differentiation of waste.
- Reuse: reduction of amount of items that go into the waste stream by reusing.
- Recycle: correct differentiation of materials.

Other measures that contribute to a safe handling of the waste are:

- Location of storage area in each ward; identification of safe transportation paths through the structure.
- Sorting and handling of waste in the storage area.
- Identification of optimal disposal methods and related supplier companies.

4.2 Questionnaire

In order to detail all the phases linked to the medical waste, from its production to the final disposal, it is necessary to identify and involve all personnel of the healthcare structure that has any relation with this process and personnel of the external company in charge of collection and disposal. The assessment model proposed in this paper makes use of a questionnaire elaborated by the research time in collaboration with the responsible of the medical waste management of the analyzed hospital.

Data on the amount of waste generated by each ward were gathered from the waste management model (MUD) and from the outsourced disposal companies.

In Figure 3 the model of the questionnaire used in the study is presented.

5. Case study

A waste measurements campaign for assessing waste flows and costs has been carried out in a small size hospital of a territorial zone of Marche region, in central Italy, defined as Area Vasta. The term "Area Vasta" defines an organizational level below the central health management system of the region, that has to carry out

Hospital/healthcare structure	Ward	Number of beds	Responsible for questionnaire administration	Personnel involved in questionnaire compilation	Disposal companies
Medical Waste Production – MWSA Phase					
Assessment of waste flow produced by each ward	Yes	No	Source/ward	Identified anomalies	Kg/bed*day
Medical waste (all classes: HMW-I, HMW, NHMW)					
Solid/general waste					
Medical Waste Storage – MWSA Phase					
Assessment of waste movements and storage	Yes	No	Type/ location	Identified anomalies	Notes
Recyclable containers					
Transient storage location					
Means of transportation					
Final storage location					
On-site treatments					
Medical Waste management assessment – MWSA Phase					
Assessment of management procedure implemented	Yes	No	Responsible	Identified anomalies	Notes
Medical waste management plan					
Source reduction plan					
Medical Waste Stream Handling-MWSH					
Assessment of training and procedure for waste handling	Yes	No	Responsible	Identified anomalies	Notes
Waste segregation guidelines					
Waste segregation procedures					
Personnel training on medical waste regulation and correct handling practices					
Risks evaluation					
Costs evaluation					
Medical Waste Stream Minimization-MWSM					
Assessment of waste minimization procedures	Yes	No	Responsible	Identified anomalies	Notes
Recycling program					
Waste traceability program					
Waste reduction monitoring					

Figure 3.
Self-assessment questionnaire

administrative, technical, logistic functions that are not convenient to manage centrally. The Area Vasta is not only the representation of an administrative level, but also the reference for a catchment area with a variable geometry defined with respect to the epidemiology hence to the needs and not necessarily coincident with provincial boundaries, capable of effectively guarantee the territorial health planning and the integration of functions.

The examined hospital has a total of 135 beds and is home to eight different hospital wards: general ward, surgery, emergency rooms, intensive care, pediatrics, obstetrics and gynecology, gastroenterology, urology, pneumology.

The pilot study on medical waste management optimization has been requested and approved by top management of the hospital for assessing the waste generation within the structure and implement a series of measures for reducing non compliances and related risks, as well as quantities and costs.

The study was carried out for one year and involved a selected classification of workers that have a hand at handling different phases of the waste flow (generation, storage, treatments, etc.), as well as managers and staff (environmental safety and health unit, maintenance engineer, administration), and the personnel of the outsourced company in charge of collection, transportation and disposal of the waste.

The top management assigned the responsibility for implementing and coordinating the study to a team composed by the hospital administrator, the head physician and charge nurse of each hospital ward, the administrative in charge of the waste management documents, the head of the hospital pharmacy, the research team of Mechanical Plants group of Università Politecnica delle Marche and a responsible for the outsourced company.

The data were obtained through the questionnaires elaborated by the group and submitted to a selected sample of personnel involved in the waste management process in the different wards; it was asked to provide information on waste management practices including the generation, collection, segregation, cleaning, storage and the amount of wastes generated, including general wastes, infectious wastes and other wastes.

The parameters used for determining the medical waste production factors in the analyzed structure were:

- daily quantity of waste for bed (kg/bed*day); and
- daily quantity of waste for number of days in bed (kg/patient*day).

5.1 Questionnaire results

From the questionnaire have been outlined some criticalities in the management and handling of the waste produced by the structures; the main anomalous behavior detected was the high amount of solid waste going into the medical waste stream in particular in the following wards: surgery, obstetrics and gynecology, emergency room.

For this reason and due to the large amount of data requested by the questionnaire and the wide range of questions, in the first phase of the campaign it was decided to address only this issue.

During the research the following tasks were performed:

- waste assessment: examination of waste transfer documentation (MUD), and of outsourced disposal companies database to determine waste flows;
- identification of non-compliances and abnormal behaviors;
- selection of waste generator activities that need improvement; and
- implementation of corrective actions.

5.1.1 Waste stream assessment. Data on medical waste quantities (measured as kg/bed*days) were obtained for each ward; it was decided to exclude from the examination the laboratory. In the Table III the information gathered from the questionnaire are presented.

From the results it is possible to identify that wards of obstetrics and gynecology, and surgery produce the higher amount of medical waste with a percentage of 82 percent and 80 percent on the total quantity of waste. In Figure 4 is presented the relationship between medical waste and general waste production in the analyzed wards. Figure 5 shows the distribution of the waste production in each ward.

Wards	Number of beds	Medical waste (Kg/ bed*day)	Medical waste (Kg/ ward*day)	Total waste (Kg/ bed*day)	General waste (Kg/ bed*day)	Medical waste on total waste stream (%)
General ward	24	1.55	37.2	2.28	0.73	68
Surgery	14	2.2	30.8	2.68	0.49	82
Emergency room	5	1.49	7.45	2.01	0.52	74
Intensive care	12	1.5	18	2.2	0.7	68
Pediatrics	15	1.37	20.55	2.21	0.84	62
Obstetrics and gynecology	20	2.1	42	2.62	0.52	80
Urology	14	1.48	20.72	2.27	0.79	65
Pneumology	14	1.21	16.94	1.92	0.71	63
Gastroenterology	15	1.38	20.7	2.06	0.67	67
Total	133		214.36			

Table III.
Waste production in the analyzed hospital wards

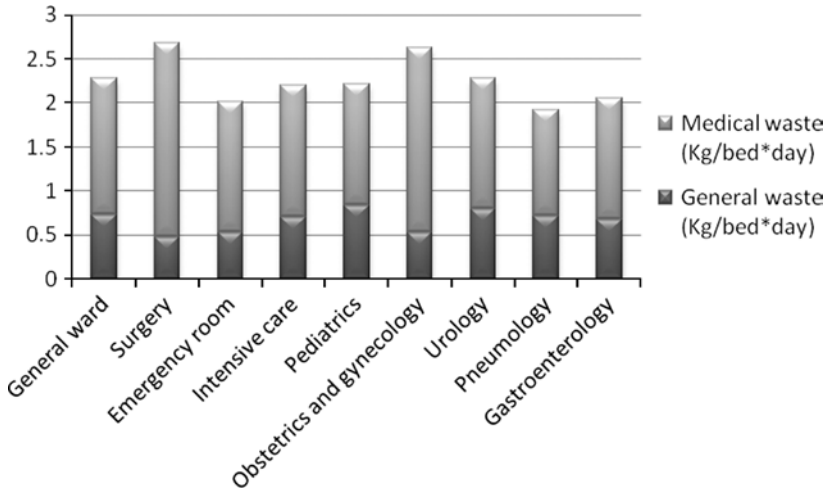


Figure 4.
Production of medical waste versus general waste on different wards

In Figure 6 is represented the deviation of the medical waste quantity produced in each ward (expressed as kg/bed*day), with respect to the average value of 1.58−kg/bed*day. From this graph is even more evident the contribution of the two above mentioned wards on the total amount of medical waste generated by the hospital.

5.1.2 Data interpretation and corrective actions proposed. The results outlined an anomalous behavior in the medical waste stream of two wards: surgery and obstetrics and gynecology.

The analysis of the questionnaire together with the inspections carried out from the working group in the mentioned wards allowed to identify the main reasons at the origin of the anomalous behavior.

The main anomalies that have been detected are related to the differentiation of waste stream and to the placement of medical waste containers.

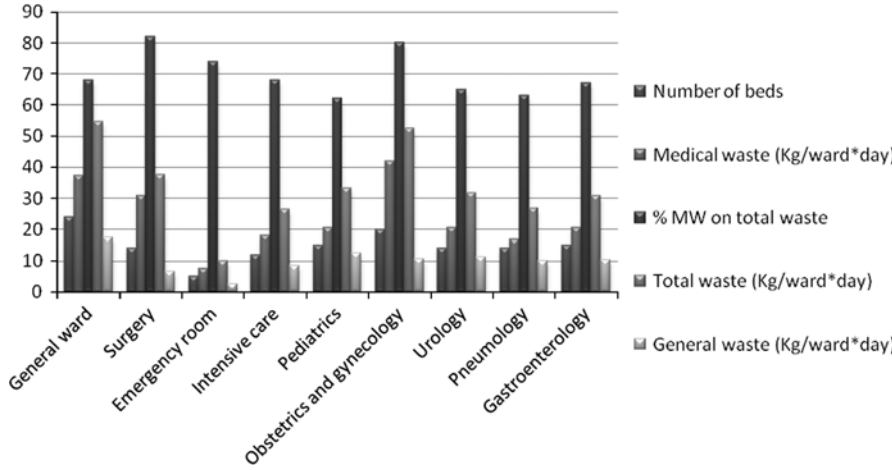


Figure 5.
Percentage of medical waste production in the different wards

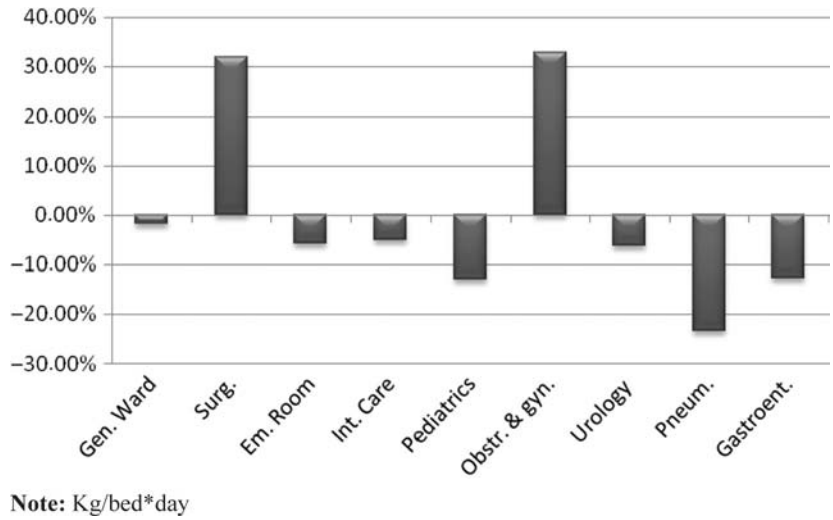


Figure 6.
Deviation from the average value of medical waste produced

In particular has been discovered that there is an high amount of diapers going into the medical waste container in the Obs. & Gyn. ward and that different types of general waste such as plastic bottle, paper, cans, etc., that can be assimilated to domestic waste, also goes into the medical waste containers in both wards.

From the inspections on the wards and the interviews with the personnel involved, have been hypothesized the following reasons for those anomalies:

- low awareness of the personnel toward the effects of this misbehavior;
- low level of knowledge of personnel in relation to what is appropriate or not for placement into medical waste containers (yellow bags); and

- wrong placement of medical waste containers trough the ward, in places in which they can easily collect general waste (as an example a yellow bag was placed next to the area of diapers change and the general waste containers was placed at the opposite side of the room).

Another important source of waste being erroneously disposed as medical waste is represented by the wraps used to package the materials for steam sterilization before going into the surgery suite. This material after being sterilized is one of the cleanest wastes produced in the hospital and therefore does not need to be treated as medical waste.

The working group together with the top management, decided to focus on this issues and to propose the following corrective actions in order to address the identified problems and reduce their impact.

Corrective actions implemented are:

(1) Train staff as to what is appropriate/inappropriate to place in the medical waste stream and sharps containers.

(2) Enforce training with signage as to what is appropriate/inappropriate for placement into yellow bags.

(3) Poster explaining what should not be disposed into yellow bags placed in each ward.

(4) Review the placement of medical waste containers throughout the hospital and remove or relocate them from areas where they are not needed or likely to collect solid waste.

(5) Definition of a procedure (in collaboration with the operating room nursing supervisor) for recycling wrap used to package all materials for steam sterilization:
   - definition of a procedure for removing wrapping material from the surgery suites;
   - definition of recycling containers locations; and
   - training of all staff involved in the process (from segregating the wrap in the surgery suite and placing it into storage).

(6) Document the reduction in the medical waste generation from removing solid waste from the yellow-bag waste stream.

The measurement campaign was repeated in the two identified wards after a period of six months; it has been outlined a decreasing of medical waste and an increasing of general waste and a decreasing of costs for managing and disposing of medical waste as shown as shown in Table IV.

5.2 Critical evaluation of the outsourcing service and improvement prospective

The hospital contracted with an outsourcing company to manage the collection, transportation and disposal of the waste. An analysis on the benefits and limitation of the provided service has been performed by the working group and a series of measure for decreasing the waste quantities and improving the flow have been proposed.

Table IV.
Decreasing of quantities and costs of medical waste after implementation of corrective actions

Ward	Medical waste (Kg/bed*day)	General waste (Kg/bed*day)	Decreasing of medical waste (%)	Medical waste before corrective actions implementation (Kg/year)	Medical waste after corrective actions implementation (Kg/year)	Average cost before corrective actions implementation (€)	Average cost before corrective actions implementation (€)
Surgery	1.9	0.78	13.6	11,242	9,709	8,319	7,184
Obstetrics and gynecology	1.78	0.85	15.2	15,330	12,994	11,344	9,615
Total	2.68	1.63		26,572	22,703	19,633	16,800

The main reasons for outsourcing a service, in the healthcare sector, is related to costs containment and efficiency improvement (Shinkman, 2000; Roberts, 2001; Young, 2002, 2005; Billi *et al.*, 2004); moreover, the outsourcing support activities healthcare organizations can concentrate on core competencies (Willcocks and Currie, 1997).

If benefits related to costs reduction are easily measured, in order to assess the effectiveness of the service provided and the possible areas of improvement, a series of meeting between the working group and the responsible of the outsourced company have been organized for analyzing the current situation at the hospital and in some Italian healthcare structures known for their commitment in waste management optimization. As an example the S. Raffaele hospital in Milan, from 2001 adopted the use of reusable waste containers; data of 2008 are presented Table V.

The analysis identified the following measures to implement in collaboration with the outsourcing company, for reducing the total amount of waste and monitoring its stream:

- use of reusable sharp containers;
- use of reusable waste containers; and
- a pilot study for introducing a traceability system (in accordance with the Sistri system that should enter into force from June 2012).

Regarding the effects of the first two actions, it has been estimated that the use of reusable sharp and waste containers allowed the diversion of about 3.5 tons of medical waste in six months.

Regarding instead the pilot study, it was experimented, in the surgery ward, in collaboration with the outsourcing company a traceability system. The company provided the reusable containers and the bar code applied by the personnel in charge; the code allowed to identify the hospital and the ward. When the container arrive at the disposal site of the company, it is weighted and the information related to the type and amount of waste, and the ward that generated it, are stored in a database. This procedure permitted the calculation automatically and precisely of the amount of waste produced in the analyzed ward and the relative costs associated to its disposal. Moreover it has been possible to monitor the waste production trend during the time, assessing the impact of the introduction of the procedure for removing wrapping material from the surgery suites.

Interviews with the responsible on the subject outlined the main risks related to the outsourcing of the waste management service: difficulty in monitoring suppliers' performances, discontinuity in service level, issues related to accountability and confidentiality of handled data, high dependency from one supplier and loss of flexibility.

Total amount of waste produced (Kg)	Estimated weight of single use containers (Kg)	Saving obtained by the adoption of reusable containers (€)	Decreasing of the heat produced from the combustion (KJoule)
1,080,000	232,000	255,207	$8*10^{12}$

Source: Mengozzi Company

Table V.
Impacts of reusable waste containers

It has been stressed that in order to improve relationship with outsourcing company and their relative performance, it is of fundamental importance to involve them in the waste optimization plan and in the relative training.

6. Conclusions

This work has been requested and supported by the management of the healthcare structure analyzed, and represents a first step in the implementation of a policy in the that consider waste management as one of the fundamental process for the proper functioning of the hospital. The results presented in this paper represent the preliminary but very encouraging effects of the developed model applications.

The questionnaire allowed the outlining of several anomalies and issues that will be addressed in the prosecution of the work, this will lead to an optimization of the entire waste stream with a consequent reduction of costs, resources, environmental impacts and risks associated.

As main result of this first phase, a series of guidelines has been elaborated by the research team and relative procedures has been implemented in each hospital ward by the involvement of all personnel dealing with waste management and handling and of the medical staff; the situation has been reevaluated after a period of six months.

It was demonstrated that the implemented strategy had a significant effect in reducing the quantity of medical waste (avoiding general solid waste going into the medical waste stream), and the relative costs.

It is important to outline that those reductions has been calculated taking into account only the two wards selected (Obstetrics and Gynecology, and Surgery) and it stands to reason to hypothesize that the application of the same corrective actions to the entire healthcare structure (including not only all the wards but also laboratories and technical services) could enhance the already encouraging results.

One other important results has been the involvement of the outsourcing company in the waste management optimization plan, cooperation that lead to a significant impact in terms of waste reduction (with the introduction of reusable containers) and waste traceability (with the introduction of the barcode system).

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Further reading

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