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The creation and monitoring of a network for solid healthcare waste management

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Abstract: Healthcare waste mismanagement constitutes a serious environmental and sanitary problem, especially in developing countries. This article describes the strategy and the methodology of the implementation of a national network for healthcare waste management by a non-profit organisation in Lebanon, taking into consideration environmental, social and economic issues. It presents a holistic description of the main aspects of this crucial sustainable development topic: the elaboration of the strategy and the selection of the optimal treatment technique based on an analysis of the context; the training on waste minimisation and waste management issues inside hospitals; the waste transportation and treatment procedures; the quality management of the process; the evaluation and the monitoring of the produced quantities and the established system; the optimisation of sterilisation parameters and process in order to reduce sterilisation time and fuel consumption.

Keywords: healthcare waste; HCW; management; treatment; network; strategic plan.

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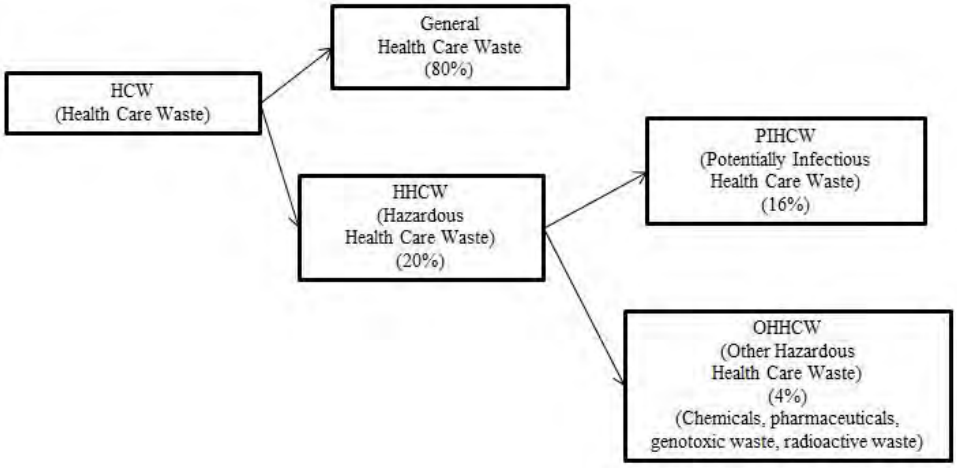
1 Introduction

Healthcare waste (HCW) management is a high-priority environmental concern in developing countries because poor management of this type of waste causes environmental pollution and health problems due to the proliferation of viruses and micro-organisms as well as contamination of ground water by untreated HCW in landfills (Dursun, 2011). The growing number of healthcare facilities directly impacts the generation of HCW (Altin et al., 2003; Kuo et al., 1999; WHO, 1999; Alagoz et al., 2007). Because hospital waste management has become a subject of interest, hospital administrations are struggling with lot of problems while trying to avoid wrong practices such as disposing of either part or all of HCW that is untreated and mixed with municipal waste in landfills (Karagiannidis et al., 2009). Numerous definitions of HCW can be found in the literature and relevant legislation (Komilis et al., 2012; Alvim-Ferraz and Afonso, 2003). According to the WHO (2011b), HCW can be divided into two major categories: general waste, which represents 80% of total HCW and hazardous healthcare waste (HHCW), which represents 20% of total HCW. Explicitly, HHCW includes potentially infectious healthcare waste (PIHCW) (16% of HCW) and other hazardous healthcare waste (OHHCW) (4% of HCW), which includes different categories: chemicals, pharmaceuticals, genotoxic waste, radioactive waste and heavy metal waste (Figure 1). If handled improperly, HCW is considered to be a major risk to public health and safety because the mismanagement of HCW could lead to death and disability (WHOb, 2013; Alagoz, 2008). PIHCW will extend its potential infectious risk within all other categories of HCW if not segregated properly. In fact, PIHCW contains harmful microorganisms that may spread infection to hospital patients, healthcare workers and the general public either through direct contact or indirectly through environment pollution and the transmission of infectious diseases (WHO, 2013b; UNEP and CalRecovery, 2005; Pichtel, 2005) when improperly stored, transported, treated, or disposed (Karagiannidis et al., 2009). Thus, untreated infectious hazardous waste can have effects on water, soil and air and could significantly affect public health (RNSSL, 2012). Therefore, a vigorous environmental waste management system is recommended (Pichtel, 2005; Mbongwe et al., 2008). Despite the growing number of healthcare facilities and the existence of a legislative framework and an accreditation system for

hospitals, few Lebanese healthcare institutions treated their HHCW before disposal until 2003. In addition, treatment was often performed improperly. The majority of hospitals were disposing of their waste without treatment and there was no national solution for HCW management. In response to this critical problem, the NGO arcenciel, with the scientific support of the Faculty of Infirmary Sciences of Saint Joseph University of Beirut (USJ), built a strategic plan that aimed to ensure a sustainable solution for HCW, starting with the proper management of PIHCW because this category forms the large majority of HHCW. The purpose of this work is first to describe the different steps of the establishment and the implementation of the new national network for PIHCW management in Lebanon and then to analyse the main results of the implementation of the network on the field. The main field results discussed include sterilisation parameters and optimisation, treatment centre design, quality management and waste generation. The approach used for the implementation of this network can be considered very innovative, notably because it has been initiated and is being operated by an NGO on a national level. The creation of this network has been considered a success by LIFE (the financial instrument of European Union). The description of the methodology adopted and the analysis of the results would be very useful for the replication of the experience in different countries willing to implement or improve their HCW management systems.

Figure 1 Composition of HCW



2 Materials and methods

To elaborate the strategy to be implemented, a legal, economic, environmental and technical analysis was conducted. Many international and national regulations were taken into consideration in order to respond to the relevant legislative, quality and safety requirements. The context specific to Lebanon has been deeply analysed in order to determine if hospitals were able to manage individual treatment facilities, whether the PIHCW treatment centre was of interest to the private sector and the appropriate type and number of service providers. To determine the capacities of the treatment facilities, the quantities of PIHCW produced were evaluated first. In fact, to allow for the consideration

of the various treatment options (Tsakona et al., 2007), it is important to know the quantity of waste generated. The main methods for medical waste treatment have been evaluated to select the optimal treatment technology. The advantages and disadvantages of the different methods have been compared, using a compatibility matrix considering different criteria proposed by the coalition Health Care Without Harm (HCWH) (2001) and considering the characteristics of the different PIHCW treatment options provided by the WHO (2005). Sterilisation parameters have been determined according to different references. To reduce the consumption of energy of the process, a heat exchanger has been installed. Different biological, chemical and physical indicators have been selected to test the efficiency of the sterilisation.

3 Theory and calculation

3.1 Regulations

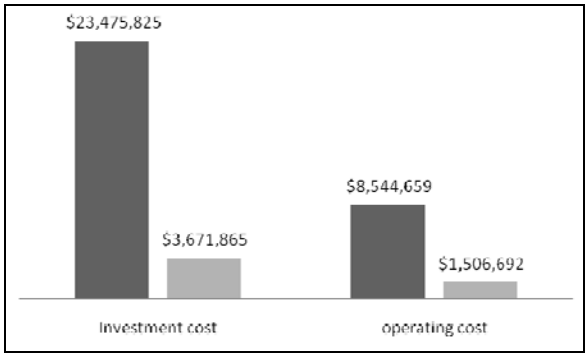
Many international and national regulations have to be taken into consideration for the establishment and the implementation of a waste management strategy on a national level. In Lebanon, most important legislation includes: the law 64 (1988), the Lebanese decree 13389 (2004), accreditation standards and guidelines for hospitals in Lebanon (2010), the Kyoto Protocol (1997), the Stockholm Convention (2001), the Basel Convention (1992) and WHO standards (1999, 2005, 2011a, 2014). The decree 13389; 2004 (amendment of the Lebanese decree 8006; 2002) is the actual point of reference in terms of national legislation concerning the management of waste by healthcare institutions. This decree specifies the categories of wastes generated by healthcare institutions and requires health institutions to treat their hazardous waste while preserving the environment and public health. As part of the reform of the health sector, the Ministry of Public Health has developed accreditation standards and guidelines for hospitals in Lebanon, including a section specific to waste management within hospitals, counting eight standards.

3.2 Socio-economic context

The Lebanese economy is based primarily on service sectors that include commerce, tourism, financial services, healthcare and higher education. The number of healthcare facilities has increased in Lebanon within the past decade, while the Lebanese healthcare system suffers from high spending making up 7% of the gross domestic product (GDP) in 2010 (WHO, 2013a). According to the evaluation by the Environmental Resources Management (ERM) consulting company in 1999, it was estimated that Lebanon produced 11 tons/year of PIHCW, which represent 20% of the total medical waste. PIHCW production in Lebanon was expected to be approximately 0.4% of the total solid waste in the country. Lebanon has a total of 163 hospitals (i.e., 15342 beds) spread throughout the country, of which 135 (82.82%) fall under the private sector, i.e., 12648 beds (82.44%) and 28 (17.18%) under the public sector, i.e., 2550 beds (16.62%) (RNSSL, 2012). The country also contains five Palestinian refugee hospitals (209 beds). Thus, the healthcare sector in Lebanon is mainly private (RNSSL, 2012). The health sector in Lebanon is characterised as a chaotic sector with a surplus of beds, extra investment in equipment and a dominance of hospitals with a bed capacity lower than

100 (approximately 75% of hospitals) (RNSSL, 2012). The occupancy rate of hospitals does not generally exceed 55% (RNSSL, 2012). After having conducted a financial analysis, it seemed inappropriate to multiply the investment by each hospital to treat PIHCW. Semi-centralised processing stations could serve several hospitals at once. A study conducted within the framework of the project LIFE 05 TCY/RL/138 in 2006 showed that the total cost of processing 1 kilo of PIHCW is 2.25 times higher when each institution treats its PIHCW separately. In fact, if we compare the total individual investment costs (investment cost per hospital * number of hospitals) to investment costs in the case of a national solution (investment cost per treatment centre * number of treatment centres), total investment costs are lower in the second case. It should be mentioned that investment costs include autoclaves, accessories (boilers, filters…), environmental impact assessments, construction of a treatment centre and in the case of a national solution, collection vehicles. In addition, if we compare operating costs in the case of an individual solution (operating costs per hospital * number of hospitals) to operating costs in the case of a national solution (operating costs per treatment centre * number of treatment centres), operating costs are lower in the second option. It should be noted that operating costs include consumables, human resources, insurance, maintenance and amortisation. Thus, investment and operating costs are significantly higher in the case of an individual solution, as shown in Figure 2.

Figure 2 Cost comparison between individual and network solution. individual solution (dark), network solution (light)



3.3 PIHCW treatment technologies

The main methods for medical waste treatment are autoclave, microwave disinfection systems, chemical disinfection and incineration (Xie et al., 2008). The main criteria proposed by HCWH (2001) to evaluate treatment technologies include: efficacy, emissions and waste residues, the reduction of waste volume and mass, occupational safety and health, the level of commercialisation, cost, regulatory acceptance; and community and staff acceptance. A comparison between the different treatment methods using a compatibility matrix shows that the steam sterilisation in autoclaves is an optimal technique that takes into account environmental, economic and social criteria. When compared with other treatment methods (incineration, chemical sterilisation and microwave technology), the capital and the operating costs and the adverse effects on health and the environment are relatively lower, as shown in Table 1. These results

confirm those shown by Dursun et al. (2011). In fact, controversy exists regarding possible long-term environmental effects especially of hypochlorite and its byproducts in waste water when chemical disinfection is used (HCWH, 2001). Microwave disinfection systems have a low level of commercialisation in Lebanon. As for HCW incineration, the main disadvantages are the emission of pollutants in the atmosphere, some of them having known effects on human health and are environmentally toxic (HCWH, 2001; Alvim-Ferraz and Afonso, 2003; Xie et al., 2008; Diaz et al., 2005; Chen et al., 2012) and the fact that incineration presents significant capital and operating costs (HCWH, 2001; Alagoz et al., 2007). These disadvantages often lead to increasing community opposition to incineration (Karagiannidis et al., 2009), especially in Lebanon. Besides, Lebanese decree 13389/2004 prohibits incineration of PIHCW and recommends the use of sterilisation for the treatment of PIHCW. The basic principle of steam sterilisation, as accomplished in an autoclave, is to expose each item to direct steam contact at the required temperature and pressure for the specified time (HCWH, 2001). The sterilisation method applied includes a double-wall circular vessel where the shredding, stirring and dehydrating of the wastes occur (Karagiannidis et al., 2009). Moist heat destroys microorganisms by the irreversible coagulation and destruction of enzymes and structural proteins (HCWH, 2001). Prions, which are extremely resistant to conventional inactivation procedures including irradiation, boiling, dry heat and chemicals, could be inactivated in autoclaves for dry waste at 134°C for 60 minutes (EHRS, 2011). Large volumes of infectious liquid waste containing prions can be treated with 1N NaOH followed by autoclaving at 132°C for 4.5 hours (EHRS, 2011). HCW shredding during sterilisation reduces the risk of accidental injury or incision by sharps, increases overall waste exposure to heat and makes HCW unrecognisable. The crushed and sterilised waste obtained as a result of this process is not recognisable and is no longer hazardous. Using this method reduces the total volume of waste by 80% (HCWH, 2001). In addition, if waste is segregated before being processed, there will be no harmful gas emissions by autoclaving (Karagiannidis et al., 2009). In central sterilisation treatment systems, sterilised HCW would then have the characteristics of domestic solid waste at the end of the treatment process. Sterilised waste is transported and disposed at a municipal solid waste sanitary landfill (Alagoz et al., 2008; Karagiannidis et al., 2009).

Table 1 Compatibility matrix of PIHCW treatment techniques

	Autoclave associated with shredding	*Chemical disinfection*	*Microwave*	*Incineration*
Emissions and waste residues	+	–	+	–
Efficacy	+	+	+	+
Regulatory acceptance	+	+	+	–
Reduction of waste volume/weight	+	–	+	+
Level of commercialisation	+	+	–	+
Cost	+	+	+	–
Community and staff acceptance	+	–	+	–
Occupational health and safety	+	–	+	–

Notes: (+) Indicates relative high performance of the technique for each studied criteria,
(–) Indicates relative low performance of the technique for each studied criteria

3.4 Operation and organisation

The different operational and organisational options depending on the number and type of operators have been compared considering different criteria: mission, costs, sustainability and effectiveness. Analysis of the socio-economic context (cf. *paragraph 3.2*) shows that an economy-of-scale strategy should be adopted, especially because hospitals are facing economic difficulties in Lebanon. In addition, it is easier for the concerned authorities (mainly the Ministry of Environment in Lebanon) to control and audit five to six centres that cover all Lebanese hospitals than to control individual autoclaves in every hospital. Moreover, the treatment of medical waste is a delicate process, requiring trained human resources, advanced expertise, maintenance and daily monitoring. Management of the process is very difficult when it is the same organisation that produces, sorts, collects and treats waste. When not controlled or poorly controlled, the sterilisation process can be inefficient. A limited number of PIHCW sterilisation centres reduces the cost of experience. Besides, the mission of healthcare facilities is to treat people. Therefore, the outsourcing of waste treatment services offers the hospital the opportunity to refocus on its core activity. The minimisation of PIHCW quantities is crucial to reduce treatment costs for hospitals and the impact on public health and the environment. Awareness and training related to the adequate sorting of PIHCW allows a reduction in the quantity of PIHCW generated. The consequence of this minimisation would be a reduction in quantities treated by the service provider. If we consider a pricing per kilogram (price in accordance with the weight of the waste), expected benefits would be reduced as well. Thus, waste minimisation is not compatible with the interests of a service provider in the private sector. Therefore, the service provider should preferably be a non-profit organisation. A multitude of investments in equipment by several providers is neither justifiable nor cost effective considering the low PIHCW production in Lebanon. In addition, the successful coordination between multiple competing parties would be very difficult in the case of machine failure, war or other crises. Thus, as the public sector did not implement a solution for HCW management, one NGO should provide training, collection and treatment.

3.5 Waste minimisation and sorting

If HCW sorting is not applied sufficiently, risks are inevitable for both workers and patients (Alagoz et al., 2007). By sorting waste, appropriate treatment techniques can be applied to each separate waste stream (HCWH, 2001). Segregation policy is a key element in PIHCW minimisation (HCWH, 2001). Another crucial reason for segregation has to do with the consequences of introducing OHHCW into treatment systems of infectious waste. In fact, errors of sorting can be harmful to human health and the environment. In addition, an autoclave machine can be affected by the presence of inappropriate waste inside, such as radioactive, cytotoxic and chemical waste (HCWH, 2001). Therefore, the main staff categories involved in HCW management in hospitals should receive appropriate training. These categories include: hospital managers and administrative staff responsible for implementing regulations of HCW management; medical doctors, nurses and assistant nurses; and cleaning staff. The WHO recommends

adopting variable pricing (price per kilogram) in order to provide incentives for proper segregation and waste reduction (cost saving) (WHO, 2014).

3.6 Waste collection

According to WHO safety standards (1999), the transport of wastes from a healthcare centre to a waste treatment centre implies a specially equipped vehicle exclusively used for PIHCW transportation. The internal surface coating material of the vehicle should allow it to be steam-cleaned and the internal angles should be rounded. After each collection of PIHCW, the interior of the vehicle should be systematically cleaned and disinfected. The vehicle should be closed except when loading or unloading. If PIHCW is stored at a temperature lower than 5°C, it can be collected within seven days (Alagoz et al., 2008). Otherwise, PIHCW should be collected within 48 hours during the cold season and within 24 hours during the hot season according to WHO recommendations (1999).

3.7 Sterilisation parameters

The sterilisation parameters have been determined according to different references. The maximum sterilisation temperature proposed by the WHO is 138°C for a sterilisation duration of 5 min (WHO, 2011a). The factor of thermal inactivation for the couple [temperature (°C), time (min)] has been compared to the reference couple (121°C; 30 min) (Karagiannidis et al., 2009), using the formula

$$\text{Log } t = \frac{T - T^*}{z} + \log F$$

F the number of minutes required to kill a known population of microorganisms

t time

T temperature

T^* reference temperature

Z factor of thermal inactivation.

To reduce energy consumption, a heat exchanger has been installed.

3.8 Sterilisation indicators

The evaluation of the efficiency of the treatment method is very important because the treated infectious hospital wastes will finally be disposed of in municipal waste landfills (Karagiannidis et al., 2009).

According to HCWH (2001) recommendations, the ability of the steriliser to reach the physical parameters (temperature and pressure) necessary to achieve sterilisation is monitored by mechanical, chemical and biological indicators.

4 Results and discussion

4.1 General characteristics of the network

As a result of the analysis of the previous aspects, a Lebanese waste management network operated by the NGO arcenciel has been created. The network includes five treatment centres covering all regions in Lebanon. Each treatment centre can be a backup system for all other centres when needed and waste can be easily transported from one centre to another. For over ten years, the national network for PIHCW management provides a unique and comprehensive service in Lebanon, including the proper training of healthcare institutions' staff, the collection and transportation of PIHCW from the healthcare institutions in specialised vehicles and PIHCW sterilisation.

4.2 Training and technical support

arcenciel provided specific training sessions to the main hospital staff categories involved in HCW management once their institution began the implementation of a PIHCW management system. An assessment regarding HCW management has been realised in each organisation before training in order to adapt the training content to the existing situation and thus increase its effectiveness. Special training has been prepared in collaboration with the Faculty of Infirmary Sciences of Saint Joseph University of Beirut and provided to healthcare institutions' staff. The training emphasised sorting modalities at the point of generation as a key element for infection control and cost saving. The training addresses the potential hazards of the wastes from an environmental and sanitary point of view and the measures to be taken in order to prevent these risks. These measures cover all stages of the management of PIHCW within the hospital: sorting, collection, intermediate storage, internal transportation and central storage, in compliance with WHO recommendations (1999, 2005, 2011a, 2014). The required work practices, sorting procedures and the use of personal protective equipment have been emphasised. An analysis of the feedback received from the beneficiaries allowed the continued improvement of the training content and methodology. Trainings have then been implemented by hospitals themselves when new methods were introduced and when employees were newly hired. All concerned employees received annual updates as well. arcenciel also provided technical support for the purchase of equipment (e.g., sharps containers, trolleys, plastic bags), for the establishment of refrigerated PIHCW storage rooms and for the administrative support for the management of HCW (quantity monitoring, procedures, key performance indicators). Training and technical support costs were included in the treatment cost. Training and awareness provided allowed a considerable and sustainable change in the cultural practices of healthcare. To date, 8,000 persons have already been trained in HCW management in Lebanon. Knowing that according to the 'polluter pays principle', hospitals should bear the costs of their PIHCW management and should therefore pay the treatment service provider for the treatment of their PIHCW, variable pricing (price per kilogram) was adopted in order to provide incentives for the proper segregation and reduction of waste (cost saving).

4.3 Collection and transportation

arcenciel collects only yellow bags that contain sorted PIHCW and sharps containers. Opened bags or bags containing hazardous waste other than PIHCW or recognisable anatomical parts are not collected. In fact, recognisable anatomical parts should not be treated in autoclaves according to the Lebanese decree 13389/2004. A radioactivity detector is used to verify that there is no radioactive material in the collected bins. PIHCW is transported by an optimised route, determined in such a way to minimise travel distances. All surfaces of the collection vehicles are easily washable and corners are rounded. The collection frequency depends on the quantity generated by each hospital and the availability of a refrigerated storage room inside the health institution.

4.4 Treatment centres

All treatment centres were the subject of an environmental impact assessment conducted by a private company authorised by the Ministry of Environment and are organised in such a way to avoid cross-contamination. All surfaces of the treatment centres are easily washable and corners are rounded. Each centre includes a refrigerated room with sufficient capacity reserved for the storage of PIHCW before treatment and a storage room of sterilised waste. The centre includes a storage room for PIHCW waste, an area for cleaning buckets, desks and lockers and a washing machine for cleaning uniforms. Facilities have been installed to evacuate wastewater and to cool machines. The centre is cleaned daily and the bins are cleaned immediately after they are emptied into the autoclave. Then, the bins are examined to detect possible causes of leakage. In compliance with WHO recommendations (1999) and upon being hired, each technician is vaccinated against hepatitis A and B, polio and tetanus and receives a training session with the precautions and measures to be taken in case of an accident. Wearing protective equipment is mandatory. Impeccable hygiene is required from technicians for reducing the risks of handling HCW. Therefore, convenient washing facilities (with warm water and soap) are available for personnel involved in the task. In addition, annual blood tests and medical examinations are carried out for the whole team.

Figure 3 The evolution of fuel consumption (see online version for colours)

4.5 Autoclaves

Each centre includes one autoclave that can reach the maximum sterilisation temperature proposed by the WHO (138°C) (WHO, 2011a). According to the specifications of purchased autoclaves, the sterilisation time corresponding to the sterilisation temperature of 138°C was found to be 7 min. Five autoclaves have been purchased: two autoclaves with a treatment capacity of 300 litres per 30 minutes average cycle time; one autoclave with a treatment capacity of 1,000 litres per 40 minutes average cycle time; one autoclave with a treatment capacity of 3,000 litres per 60 minutes average cycle time; and one autoclave with a treatment capacity of 720 litres per 60 minutes average cycle time. Regular preventive maintenance is performed on autoclaves. A calculation showed that the factor of thermal inactivation (z = 26.89°C) is more significant for the couple (138°C; 7 min) than for the couple (121°C; 30 min). Thus, the first parameters mentioned have been adopted. The installation of a heat exchanger allowed a reduction of fuel consumption of 17% (Figure 3). The required investment, including purchasing and installation costs, was equal to $1700. The payback period was five months thanks to the energy savings acquired as a result of the newly installed system.

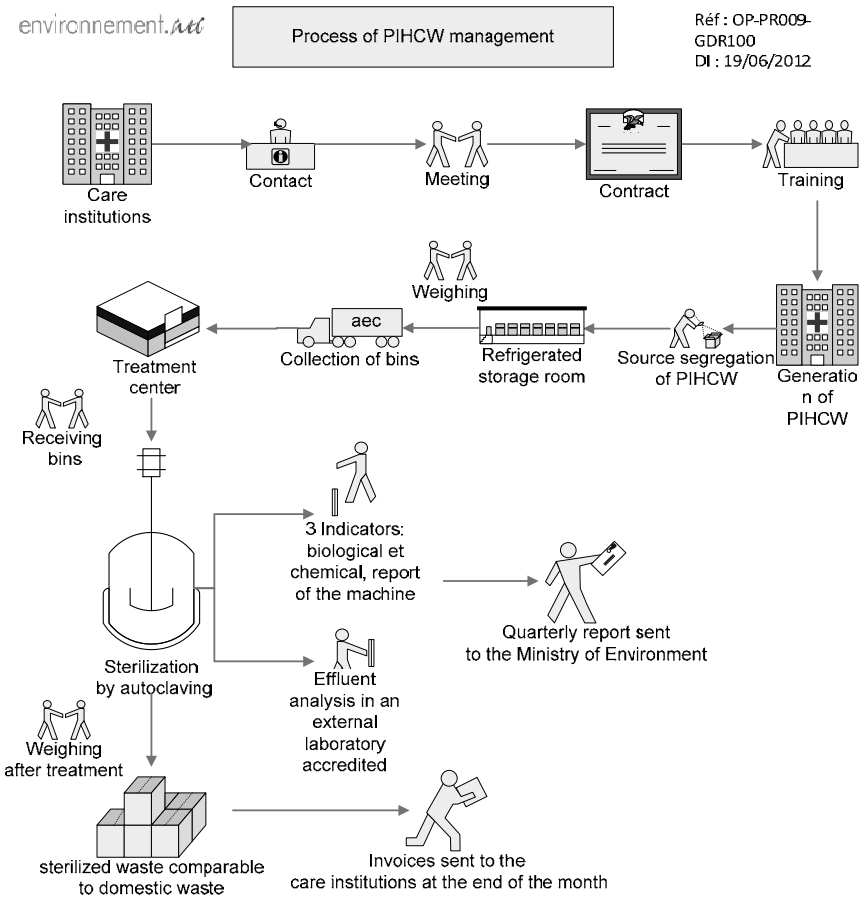
4.6 Management and control

4.6.1 Management system

The complete management system is described in Figure 4. Procedures, instructions and key performance indicators were established and used to control and monitor the PIHCW collection and treatment process, allowing for the detection and correction of non-conformities.

The traceability system is based on follow-up notebook slips. Each slip includes three boxes to be filled. The first two boxes are related to the hospital and the collector. The third box concerns the treatment centre. Upon arrival of the collection vehicle at the hospital, the collected bins are counted, weighed and loaded in the vehicle in the presence of a hospital representative. The information (weight, date and the quantity of bins) is reported on a slip that is signed by the collector and hospital representative. A copy of the slip is delivered to the hospital. Once the bins are delivered to the treatment centre, the date and the quantities received are noted by the technician in charge of the treatment. The slip is then signed by the technician. Follow-up notebook slips are sent to the service provider administration. This traceability is very useful for the monitoring of the process and the follow-up of the quantities produced by hospitals. In the case of significant variations or abnormalities, further training sessions and support are proposed for concerned hospitals. This information also allows arcenciel to submit quarterly reports to the Ministry of the Environment concerning the quantities treated for each hospital during this period.

Figure 4 The process of PIHCW management



4.6.2 Sterilisation indicators

Cycle reports printed by the autoclave show the evolution of the pressure and temperature measurements as a function of time for each cycle. The analysis of these figures allows the verification that the key parameters have reached the threshold values to ensure sterilisation.

A chemical test performed daily ensures that the sterilisation cycle was normal. It consists of coloured strips pasted on the walls of the autoclave, which change colour when the pressure and temperature reached their threshold values. The biological test consists of testing the enzyme activity in a reference sample containing spores of G. stearothermophilus, placed in the centre bottom, middle and top of the batch of waste in compliance with the recommendations of the United Nations Development Program (2013) pre-treated in an autoclave. The results of these tests are compared to ensure that treatment was effective and to identify possible disruptions. The review of the test results shows that sterilisation was efficient for all of the cycles conducted.

4.6.3 Control and monitoring

The network is a self-regulated system ensuring a triple control: arcenciel, as a service provider, is controlled by healthcare institutions because waste producers are responsible for the waste they generate until final disposal, according to the 'polluter pays principle' included in the Lebanese law 444; 2002. arcenciel exercises a control of hospitals through monitoring PIHCW quantities and reporting them to the Ministry of the Environment. As required by the Lebanese decree 13389; 2004, the Ministry of the Environment monitors the whole system and controls arcenciel facilities through environmental impact assessments, audits and regular reports.

4.7 Human resources

In a social entrepreneurship model, the team involved in the PIHCW management is multidisciplinary and well trained and consists of 42 people with extensive experience in their fields. Over 70% of these people are people with disabilities, ex-addicts, or ex-prisoners. More than 83% of the team are women when excluding the treatment centres.

4.8 Treated quantities

Approximately 6 tons of PIHCW from 105 hospitals, which represent 64.42% of the hospitals in Lebanon (i.e., 9306 beds, which is equivalent to 61.23% of all hospitals beds) are treated daily, as shown in Table 2. PIHCW is also collected from laboratories, dispensaries and clinics. Five hospitals treat their PIHCW independently outside of the network. The remaining hospitals continue to throw away their PIHCW without treatment, mainly because of the lack of government control. Thus, efforts are being made to convince these establishments to appropriately treat their PIHCW. In fact, one of the main encountered difficulties while implementing a national solution for PIHCW management was to obtain the involvement and engagement of healthcare institutions administrations and to get them to accept the 'polluter pays' principle.

Table 2 Lebanese PIHCW management network coverage in 2012

Region	*Total Number of hospitals*	*Hospitals covered by the network*	*Percentage of hospitals covered by the network*	*Total number of hospitals beds*	*Beds covered by the network*	*Percentage of beds covered by the network*
Beirut	21	17	80.95%	3206	2,445	76.26%
Metn	44	27	61.36%	4686	2,464	52.58%
Kesrouan-Jbeil	9	4	44.44%	665	387	58.20%
Chouf-Aley	12	8	66.67%	782	317	40.54%
Bekaa	24	15	62.50%	1701	1,136	66.78%

Notes: Number of hospitals and beds per region are taken from RNSSL, 2012
Number of hospitals and beds covered by the network are based on arcenciel's data

Table 2 Lebanese PIHCW management network coverage in 2012 (continued)

Region	*Total Number of hospitals*	*Hospitals covered by the network*	*Percentage of hospitals covered by the network*	*Total number of hospitals beds*	*Beds covered by the network*	*Percentage of beds covered by the network*
North-Lebanon	28	22	78.57%	2027	1,761	86.88%
South Lebanon	25	12	48.00%	2131	796	37.35%
TOTAL	163	105	64.42%	15198	9306	61.23%

Notes: Number of hospitals and beds per region are taken from RNSSL, 2012
Number of hospitals and beds covered by the network are based on arcenciel's data

5 Conclusions

Currently, approximately 65% of hospitals in Lebanon treat their PIHCW through the Lebanese network for HCW management. The complete system implemented provides a solution for PIHCW, compliant with WHO recommendations and national regulations. This solution includes specialised training, collection, treatment and final disposal. The key aspects taken into consideration in the network strategy and implementation are quantity minimisation, occupational health and safety, public health and environmental preservation, socio-economic factors, national and international standards and treatment costs and efficiency. A complete statistical study is currently being realised to compare the PIHCW generation rate per bed of different hospital categories to international references. Efforts for better accountability and awareness of healthcare institutions continue with the aim of treating the totality of PIHCW. Treatment solutions are being studied for OHHCW. The Lebanese network for HCW management implemented brings a solution to a major environmental and sanitary problem and could serve as a role model in different countries willing to implement or improve their HCW management systems. Thus, the replication of this successful experience is important, especially in developing countries suffering from HCW mismanagement.

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Abbreviations

HCW	healthcare waste
PIHCW	potentially infectious healthcare waste
HHCW	hazardous healthcare waste
WHO	World Health Organization
HCWH	Health Care Without Harm
RNSSL	Recueil National des StatistiquesSanitaires au Liban