Health Care Waste generation rates and patterns: The case of Lebanon

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ABSTRACT

The objective of this study is to analyze Infectious Health Care Waste generation rates and patterns in Lebanon. Therefore, the quantities generated during five years by 57 hospitals from a total of 163 in the country have been analyzed. The seasonal evolution of Infectious Health Care Waste production and the evolution of the evaluation of the trends over years have been studied. Besides, the generation per capita have been estimated and compared to other countries. The variance between categories and the correlation between number of beds and Infectious Health Care Waste generation have been analyzed. The obtained results showed that the large private hospitals (over 200 beds) are characterized by their high generation rate: an average of 2.45 kg per occupied bed^{-1} day^{-1}, whereas the average generation rate for other categories is 0.94 kg per occupied bed^{-1} day^{-1}. The weighted mean is 1.14 per occupied kg bed^{-1} day^{-1}. Small public hospitals (i.e. less than 100 beds) have the smallest standard deviation: 0.13, whereas large private hospitals (i.e. over than 200 beds) have the highest standard deviation: 0.40. Infectious Health Care Waste generation has been estimated to 1.42 kg/capita/year.

The correlation between the numbers of hospitals beds in hospitals and the generation rate per bed is weak. The correlation between Infectious Health Care Waste generation per day and beds number is stronger. The total quantity produced by hospitals has increased over the five past years. These results suggest that the quantities of medical waste are not well controlled, and that hospitals have a defective monitoring management system of their waste. Annual peaks are observed in June, July, and December. Thus, this study, for the first time in Lebanon, has provided information on the infectious waste generation, allowing benchmarking between hospitals and between countries.

1. Introduction

Health Care Waste (HCW) includes all the waste generated by hospitals, private surgeries, other health care facilities, diagnostic centres, research facilities and laboratories and dental practices (Marinković et al., 2008; Graikos et al., 2010; Voudrias and Graikos, 2014).

HCW management is an imperative environmental and public safety issue, due to its potentially infectious and/or toxic character (Jang et al., 2006; Tsakona et al., 2007; Ferreira and Teixeira, 2010; Graikos et al., 2010). HCW can be divided into two major categories: general waste which represents 80% of total HCW; and Hazardous Health Care Waste (HHCW) which represent 20% of total HCW (WHO, 2011; Voudrias and Graikos, 2014). Explicitly, HHCW includes Infectious Health Care Waste (IHCW), and other HHCW which includes different categories: chemicals, pharmaceuticals, genotoxic waste, and radioactive waste. Infectious Health Care Waste (IHCW) is the waste type suspected to contain pathogens (bacteria, viruses, parasites or fungi), in sufficient concentration or quantity to cause disease in susceptible hosts (Pruss et al., 1999). Thus, IHCW management is a particularly high priority environmental concern, because inappropriate management of this type of waste may cause damage to human through injury by sharp instruments, infectious diseases such as HIV infection and hepatitis transmitted to humans due to proliferation of micro-organisms, environmental pollution and as well as contamination of ground water (Jang et al., 2006; Marinković et al., 2008; Yong et al., 2009; Graikos et al., 2010; Ferreira and Teixeira, 2010; Dursun et al., 2011).

Abbreviations: HCW, Health Care Waste; IHCW, Infectious Health Care Waste; HHCW, Hazardous Health Care Waste; WHO, World Health Organization.

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HCW management is one of component reflecting the ability of hospital to provide a good standard of care (Sanida et al., 2010). Hospitals, particularly in developing countries, usually face difficulties in monitoring HCW management in a manner to avoid wrong practices, like inappropriate HCW sorting or disposing IHCW untreated and mixed with municipal waste in landfills (Tsakona et al., 2007; Diaz et al., 2008; Karagiannidis et al., 2010; Ferreira and Teixeira, 2010). The management of HCW requires source-separation of the hazardous fraction and sorting of this into infectious and toxic sub fractions (Graikos et al., 2010). Two potential problems can be commonly faced: first; some IHCW could be placed in the non-hazardous health care stream with potential hazard of spreading infection; then, not contaminated waste could be placed in the IHCW stream, thus making the volume of IHCW larger (Graikos et al., 2010). Thus, inappropriate sorting practices can lead to increased quantities of IHCW and hence higher costs of disposal (Tsakona et al., 2007; Ferreira and Teixeira, 2010).

Approximately 10–25% of HCW is considered infectious (UNEP, 2002; Diaz et al., 2008; Shinee et al., 2008). However, the percentage of IHCW in the total Health Care Waste stream in developing countries can reach 63% compared to 51% in an industrialized country (Diaz et al., 2008). The proportion can be reduced with appropriate sorting practices (UNEP, 2002).

Types of medical establishments and the waste management capacity at hospitals have been recognized as important factors in waste management (Cheng et al., 2009; Yong et al., 2009). In fact, data from the WHO show that the amount of HCW production depends on the size and the type of medical institution, but also it differs from country to country based on their national income or their level of development (Marinković et al., 2008). High developed countries have a larger production of medical waste than middle developed and developing countries (Marinković et al., 2008). The total amount of healthcare waste generated in a hospital in an industrialized country would be approximately 1.2 to more than 200 times that generated in some developing countries (Diaz et al., 2008). The difference in quantities results from the fact that developed countries invest much more money in health systems, leading to larger amounts of medical waste generation (Marinković et al., 2008).

IHCW generation rate is one of the principal elements reflecting sorting and other waste management practices. Many studies defining HCW generation rates in different countries have been reported in literature. For instance, the HHCW generation rates of large hospitals in Korea were found to vary from 0.14 to 0.49 kg bed^{-1} day^{-1} (Jang et al., 2006), assuming 100% bed occupancy. The average HHCW generation rate was around 0.25 kg bed^{-1} day^{-1} in Bangladesh (Patwary et al., 2009, 2011). In Iran, the average HHCW generation rate ranged from 0.4 to 1.91 kg bed^{-1} day^{-1} (Taghipour and Mosaferi, 2009). In Greece, an IHCW generation rate of 1.4 kg bed^{-1} day^{-1} was reported by Tsakona et al. (2007); and an average generation rate of 0.58 kg bed^{-1} day^{-1} or 0.87 kg occupied bed^{-1} day^{-1} was reported by Sanida et al. (2010). An average generation rate of 0.54 kg bed^{-1} day^{-1} was reported in Taiwan (Cheng et al., 2009). The IHCW average rate was 0.34 kg bed^{-1} day^{-1} in Philippine; and 2.0 kg/bed-day in Portugal (Diaz et al., 2008). According to WHO (2011) East Asia, Eastern Europe and the Middle East produce 1.3 to 3 kg per bed.

Today, IHCW sorting is done at the point of generation in the majority of hospitals in Lebanon. Around 70% of produced IHCW is treated by shredding associated to autoclaving through a national network for IHCW management, operated by a Non-Governmental Organization (NGO), "arcenciel". This network provides training and awareness on HCW sorting and management for administrative staff, cleaning staff, and health care staff. Then, based on an assessment for the evaluation of IHCW generation and the availability and the capacity of refrigerated storage room within the hospital, a collection frequency is determined. arcenciel collects IHCW from hospitals on a regularly basis. IHCW is weighted in each hospital immediately before collection, in presence of one representative of the hospital, who signs the waste tracking document. IHCW is then transported to the nearest treatment centre of the network. The network includes five treatment centres covering all regions in Lebanon. Each treatment centre includes one autoclave for medical waste and can be a backup system for all other centres when needed. Every trimester, arcenciel sends reports to the Ministry of Environment, including the quantities collected from each hospital. Limited recent and reliable information is available in Lebanon on the quantities of the various types of wastes that are generated in healthcare facilities. Thus, hospitals and governmental authorities lack reference data in order to evaluate IHCW sorting and management practices. Site-specific data related to the generation rate of IHCW are necessary for assessing environmental impact and designing management strategies (Graikos et al., 2010).

The objective of this study is to calculate the average generation of IHCW per different hospital categories in Lebanon; to analyze possible statistical differentiations among those categories; and to compare calculated generation rates with other available references. Then, we will analyze the chronological evolution of IHCW during past years. This study will facilitate benchmarking among hospitals and countries, by allowing them to compare their generation rates against other hospitals and countries, which will help them to identify possibilities of improving the efficiency of their waste management system and predict their waste management costs.

2. Material and methods

Lebanon has a total of 163 hospitals (i.e. 15,342 beds) spread throughout the country of which 135 (82.82%) fall under the private sector i.e. 12,648 beds (82.44%); and 28 (17.18%) under the public sector i.e. 2550 beds (16.62%) (IGSPS, 2012). Around 75% of hospitals have a bed capacity lower then hundred (IGSPS, 2012). Hospitals started progressively to treat their IHCW in 2003. Generally, according to the Lebanese decree 13389, is considered as IHCW in Lebanon (1) any waste material that came in contact with blood and other potentially infectious fluids of the body, (2) sharps, (3) any waste produced by an isolated patient and (4) biological fluids, small anatomic parts, tissues, cultures and stocks of infectious agents.

HCW quantities can be either assessed by direct measurements at the source, by the use of questionnaires, or by the direct use of hospitals weight records (Komilis et al., 2012).

In this study, quantities were assessed by the use of the monthly records of the NGO "arcenciel", a service provider for waste collection and treatment in Lebanon since 2003.

Thus, the study is based in records of the weights of IHCW bins collected and treated by the service provider for the years 2009, 2010, 2011, 2012 and 2013. The frequency of collection depends on IHCW generation and hospitals storage capacities. When small amounts of waste are generated, IHCW is stored in specific refrigerated rooms within hospitals until a greater amount of IHCW was generated over time, before proceeding with the collection. In fact, IHCW can be stored more than a week before treatment, provided that they are kept cool or refrigerated at a temperature preferably no higher than 3 °C to 8 °C (WHO, 2013). Bins were weighted in the presence of a representative of the hospital who signs at each collection a statement of the quantities. The quantities used in this study correspond to the monthly sum of IHCW collected per hospital, and sent every trimester by the service provider to the Ministry

of Environment. From the 98 short-term hospitals that treat their waste with arcenciel, 41 were excluded from the sample because they interrupted temporally the treatment of their waste, which resulted in incomplete data. Therefore, the sample is formed of 57 hospitals, i.e. 6244 beds, from which IHCW is collected on a regular basis. Thus, the sample represents 34.97% of total number of hospitals and 40.70% of the total number of beds in Lebanon. Clinics, laboratories and dispensaries are not concerned by this study.

Theoretically, it is the number of occupied bed that is responsible of the generation of IHCW (Cheng et al., 2009; Komilis et al., 2012). The occupancy rate of each hospital was not available in this study; therefore the average hospitals occupancy rate of 58% was used in this work. In fact, in Lebanon the occupation rate is between 55% and 60%, based on the most recent National Health Statistics Report in Lebanon, issued by the Institute of Health Management and Social Protection (IGSPS), in collaboration with the Research Council of Saint Joseph University (USJ) of Beirut, the Ministry of Public Health and the World Health Organization (WHO) (IGSPS, 2012). Knowing that bed occupancy per hospital is not a readily available information (Komilis et al., 2012), reporting IHCW generation rate based on a national average occupancy rate provides an better reference value compared to an expression on a per occupied bed basis and to an expression on a per total official bed basis.

To be able to determine if the IHCW generation rate varies according to the size or type of the hospital, hospitals were divided into the following categories: (i) category A for private hospitals >200 beds; (ii) category B for public hospitals >200 beds; (iii) category C for private hospitals 100< # of beds $\leqslant$200; (iv) category D for public hospitals 100< # of beds $\leqslant$200; (V) category E for private hospitals # of beds $\leqslant$100; and (vi) category F for public hospitals # of beds $\leqslant$100.

The main features of interest for the study were calculated on the statistics software Lumiere. In order to assess the main characteristics of IHCW production for each category of hospitals, average of hospitals generation rates within each category of hospitals between 2009 and 2013, and average of standard deviations within each category of hospitals between 2009 and 2013 have been calculated, considering two occupancy rates: 100% (i.e. per official bed basis); and 58% (the national occupancy rate average).

The average IHCW generation rate was calculated from the records of collected weight, using the following formula:

$$\text{Generation rate} = \text{AVERAGE}\frac{\text{monthly quantity generated by hospital}}{\text{number of days in the month} * \text{number of beds in the hospital}}$$

Thus, the monthly average generation rate was calculated first in each hospital. Then, the average generation rate for all the targeted period was calculated for each hospital based on the monthly generation rates. Fisher test was conducted to verify if the average IHCW generation rate is significantly different between hospitals categories.

Analysis of variance has been done to verify if hospitals categories may be divided into different groups according to their average generation rate.

Correlation–calibration test was done to evaluate the correlation between IHCW generation rate (kg bed^{-1} day^{-1}) and beds number, and between IHCW generation per day and number of beds. Three different correlations tests have been conducted. The first one was done using the data set of all hospitals, combining all categories. Then, according to the results of the analysis of variance showing that hospitals may be divided into two groups according to their average, one correlation–calibration test was done for category A hospitals only and the third one for the other categories.

Generation rate trend was observed for each hospital. The evolution of the generation rate during time was observed for each hospital to see if generation rate was increasing, decreasing, or if it was stable, and thus to be able to identify potential trends. Then, the overall production between 2009 and 2013 was observed, as seasonal variations. Generation per capita was calculated to allow comparison with other countries.

3. Results and discussion

3.1. Comparison of production

Average generation rate and standard deviation for each category of hospitals are shown in Table 1. Small public hospitals (i.e. having 100 beds or less) have the smallest generation rate: 0.20 kg occupied bed^{-1} day^{-1}. Large private hospitals (i.e. having 200 beds or more) have the highest generation rate: 2.45 kg occupied bed^{-1} day^{-1}. The overall average is 0.97 kg occupied bed^{-1} day^{-1}. Small public hospitals (i.e. less than 100 beds) have the smallest standard deviation: 0.13, whereas large private hospitals (i.e. over than 200 beds) have the highest standard deviation: 0.40.

Considering that IHCW forms 10 to 25% of Health Care Waste, it is possible to deduce that WHO estimations for IHCW generation rate in the Middle East Region is between 0.75 and 0.33 kg bed^{-1} day^{-1}, i.e. an average of 0.54 kg bed^{-1} day^{-1}. In this case, the Lebanese average generation rate based on the data analyzed in this study is 44.14% above this value. Nevertheless, Lebanese IHCW generation rate is close to IHCW generation rate of 0.85 kg occupied bed^{-1} day^{-1} in Central Macedonia in Greece reported by Sanida et al. (2010); and the generation rate of 0.76 kg occupied bed^{-1} day^{-1} in East Macedonia-Thrace in Greece reported by Voudrias and Graikos (2014).

Fisher test results show that the average IHCW production of the different hospitals is significantly different (calculated fisher = 4.75); with a level of confidence of 99.89%. Weighted mean is equal to 1.14 kg bed^{-1} day^{-1} (the weighing parameter being the number of hospitals in each category), and standard deviation between means is equal to 0.62 kg bed^{-1} day^{-1}.

3.2. Analysis of variance

Analysis of variance shows that hospitals may be divided into two groups according to their average. The first group is formed by the 52 hospitals of the categories B, C, D, E, F: the mean for this group is 0.94 kg bed^{-1} day^{-1}. The second group is formed by the 4 hospitals of the category A, these 4 hospitals forming the totality of the category A hospitals in Lebanon. The mean for this group is 2.45 kg bed^{-1} day^{-1}. Thus, the IHCW generation rate is significantly higher in large private hospitals (over than 200 beds), than in other hospitals categories. These results are consistent with other studies, indicating that IHCW generation increases with an increase in facility size and activities (Mohee, 2005; Diaz et al., 2008; Cheng et al., 2009; Graikos et al., 2010). In fact, larger hospitals have greater capacity to provide infectious disease care (Cheng et al., 2009).

3.3. Correlation

Correlation test shows a low correlation between IHCW generation rate kg bed^{-1} day^{-1} and beds number. In fact, the coefficient of correlation is 0.29 and the factor a_1 = 0.0026 kg day^{-1}, a_1 being the IHCW generation per day.

If we take into consideration the category A hospitals (large private hospitals over than 200 beds) separately, the coefficient of correlation is 0.44 and the factor a_1 = 0.0065 kg day^{-1}. If we take

Table 1
Average IHCW generation rate and standard deviation for each hospital category.

Hospital category	Number of hospitals of the sample within the category	Average generation rate (kg/bed^{-1} day^{-1}) O.R. = 100%	Standard deviations O.R. = 100%	Average generation rate (kg/bed^{-1} day^{-1}) O.R. = 58%	Standard deviations O.R. = 58%
Category A: private hospitals >200 beds	4	1.42	0.23	2.45	0.40
Category B: public hospitals >200 beds	3	0.29	0.09	0.51	0.16
Category C: private hospitals 100< # of beds ⩽200	13	0.58	0.15	1.00	0.26
Category D: public hospitals 100< # of beds ⩽200	1	0.35	0.09	0.60	0.15
Category E: private hospitals # of beds ⩽100	32	0.61	0.20	1.05	0.34
Category F: public hospitals # of beds ⩽100	4	0.11	0.08	0.20	0.13

O.R. = Occupancy Rate.

into consideration hospitals from categories B–C–D–E–F (number of observations = 53), the coefficient of correlation is 0.0529; and the factor a_1 = 0.0005 kg day^{-1}.

This low correlation is at variance with results found in Greece, where a study shown an approximately linear relationship between generation of infectious waste and the number of occupied beds in the case of studying a sample of general hospitals (Sanida et al., 2010). These results can be explained by the fact that in countries where the majority of hospitals are private sector and where authorities' control is weak, other factors such as sorting practices and policies, financial means, quality standards, level of awareness and risk perception, varying between hospitals, can impact the generation rate.

Nevertheless, as shown in Fig. 1, correlation test shows a stronger correlation between IHCW generation per day and beds number: the coefficient of correlation is 0.70.

3.4. Trends

Trends observation shows that 57.14% of hospitals have an increasing trend. 33.93% have a stable trend, and 8.93% of hospitals have a decreasing trend. As shown in Fig. 2, the overall production has increased by 36.57% between 2009 and 2013. The fact that more than 66.07% of hospitals do not have stable production, and that 57.14% of those have a growing trend, suggests that more than half of the hospitals have a defective monitoring management system for their waste. This hypothesis remains to be further confirmed with a study taking into account monthly occupancy rates by hospital and other relevant indicators, such as the number of operations.

3.5. Seasonal variations

Peaks are observed during the months of July and December 2009, July 2010, June 2011 and December 2011, July 2012, October 2012, and July 2013 which can be explained by the tendency to undergo non urgent interventions during holiday periods, which results in higher occupancy rates in hospitals during these periods, and therefore a highest IHCW generation rate. Seasonal generation variation is between 14.64% in 2013 and 24.52% in 2009 and is progressively decreasing since 2009. These results contrast with others sources assumptions that seasonal variation is not significant (Voudrias and Graikos, 2014).

3.6. Generation per capita

Considering the weighted mean of 1.14 kg bed^{-1} day^{-1}, and knowing that there are 15,342 hospitals beds in Lebanon, we can estimate that the total IHCW generated in Lebanon is equal to 6,383,806 kg/year. Considering a total population in Lebanon of 4425 million (World Bank, 2012), we can estimate an IHCW generation of 1.42 kg/capita/year. This generation is high compared to other countries where IHCW generation per capita was reported, such as in Greece where a generation of 0.73 kg/cap/year was estimated by Sanida et al. (2010).

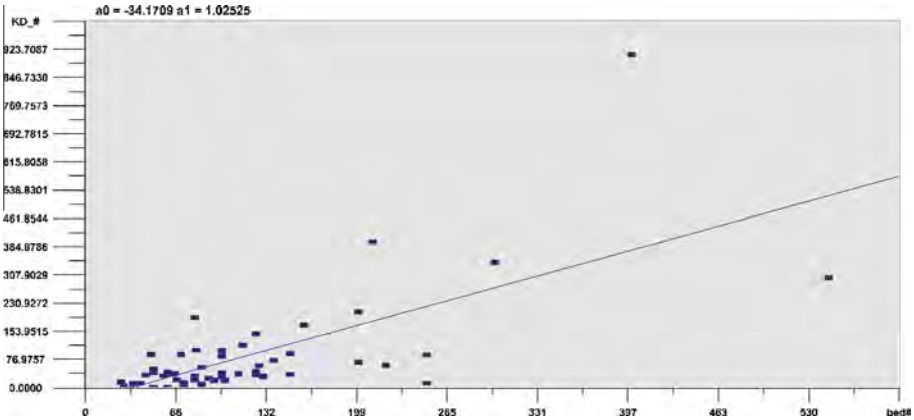

Fig. 1. Correlation between IHCW generation per day and beds number.

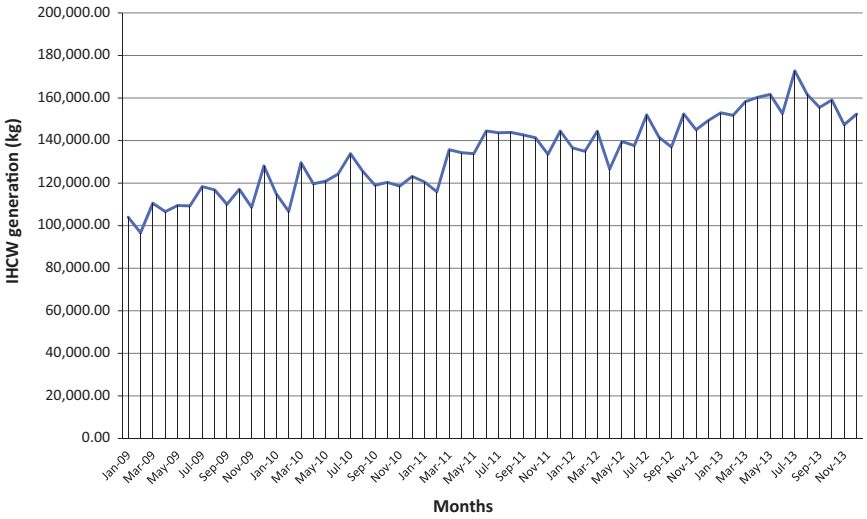

Fig. 2. Evolution of the amount of IHCW produced between 2009 and 2013.

4. Conclusion

The study allows the establishment of reference values for IHCW production per bed and per day for each category of hospitals in Lebanon. Thus, the average IHCW is 2.45 kg occupied bed^{-1} day^{-1} for large private hospitals (over 200 beds). The average is 0.94 kg occupied bed^{-1} day^{-1} for other hospitals, that is to say public hospitals and private hospitals under 200 beds. The weighted mean is 1.14 kg occupied bed^{-1} day^{-1}. These values are higher than the reference values of WHO for the Middle East (0.54 kg bed^{-1} day^{-1}), but very close to IHCW generation rate in Greece reported by Sanida et al. (2010) (0.85 kg occupied bed^{-1} - day^{-1}). Thus, this study, for the first time in Lebanon, has provided information on the infectious waste generation, allowing benchmarking between hospitals and between countries. The calculated generation rates can serve as a reference for hospitals and controlling authorities. Indeed, in case the generation rate of a hospital is far from the average rate of the category it belongs to, this could be an alerting sign on its sorting and waste management practices, whether for the hospital's administrations or the local authorities.

The correlation between the number of beds and the generation rate is weak. The growth of this rate for most hospitals suggests that the quantities of medical waste are not well controlled, and that hospitals have a defective monitoring management system of their waste. This hypothesis remains to be confirmed with a study taking into account monthly occupancy rates specific to each hospital, as well as other relevant indicators, such as the number of operations. Besides, other factors such as sorting practices and policies, financial means, quality standards, level of awareness and risk perception, which differ among hospitals, should be taken into consideration.

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References

Cheng, Y.W., Sung, F.C., Yang, Y., Lo, Y.H., Chung, Y.T., Li, K.C., 2009. Medical waste production at hospitals and associated factors. Waste Manage. 29, 440–444.

Diaz, L.F., Eggerth, L.L., Enkhtsetseg, Sh., Savage, G.M., 2008. Characteristics of health care wastes. Waste Manage. 28, 1219–1226.

Dursun, M., Karsak, E. Ertugrul, Karadayi, M.A., 2011. Assessment of health-care waste treatment alternatives using fuzzy multi-criteria decision making approaches. Resour. Conserv. Recy. 57, 98–107.

Ferreira, V., Teixeira, M.R., 2010. Healthcare waste management practices and risk perceptions: findings from hospitals in the Algarve region, Portugal. Waste Manage. 30 (12), 2657–2663.

Graikos, A., Voudrias, E., Papazachariou, A., Iosifidis, N., Kalpakidou, M., 2010. Composition and production rate of medical waste from a small producer in Greece. Waste Manage. 30 (8–9), 1683–1689. http://dx.doi.org/10.1016/j.wasman.2010.01.025 (Epub 2010 Feb 13).

Institute of Health Management and Social Protection (IGSPS), 2012. National Health Statistics Report in Lebanon (NHSRL), issued in Collaboration with the Research Council of Saint Joseph University (USJ) of Beirut, the Ministry of Public Health and the World Health Organization (WHO).

Jang, Y.C., Lee, C., Yoon, O.S., Kim, H., 2006. Medical waste management in Korea. J. Environ. Manage. 80, 107–115.

Karagiannidis, A., Papageorgiou, A., Perkoulidis, G., Sanida, G., Samaras, P., 2010. A multi-criteria assessment of scenarios on thermal processing of infectious hospital wastes: a case study for Central Macedonia. Waste Manage. 30 (2), 251–262. http://dx.doi.org/10.1016/j.wasman.2009.08.015 (Epub 2009 Oct 27).

Komilis, D., Fouki, A., Papadopoulos, D., 2012. Hazardous medical waste generation rates of different categories of health-care facilities. Waste Manage. 32 (7), 1434–1441. http://dx.doi.org/10.1016/j.wasman.2012.02.015 (Epub 2012 Mar 22).

Marinković, N., Vitale, K., Holcer, N.J., Džakula, A., Pavić, T., 2008. Management of hazardous medical waste in Croatia. Waste Manage. 28 (6), 1049–1056.

Mohee, R., 2005. Medical wastes characterization in healthcare institutions in Mauritius. Waste Manage. 25 (6), 575–581.

Patwary, M.A., O'Hare, W.T., Street, G., Elahi, K.M., Hossain, S.S., Sarker, M.H., 2009. Health and Safety Perspective on Medical Waste Management in a Developing Country: A Case Study of Dhaka City. Gemini International Limited, pp. 282–290 (ISBN: 978-0-9562303-2-4).

Patwary, M.A., O'Hare, W.T., Sarker, M.H., 2011. Assessment of occupational and environmental safety associated with medical waste disposal in developing countries: a qualitative approach. Saf. Sci. 49, 1200–1207.

Pruss, A., Giroult, E., Rushbrook, P., 1999. Safe Management of Wastes from Health Care Activities. WHO, Geneva.

Sanida, G., Karagiannidis, A., Mavidou, F., Vartzopoulos, D., Moussiopoulos, N., Chatzopoulos, S., 2010. Assessing generated quantities of infectious medical wastes: a case study for a health region administration in Central Macedonia, Greece. Waste Manage. 30, 532–538.

Shinee, E., Gombojav, E., Nishimura, A., Hamajima, N., Ito, K., 2008. Healthcare waste management in the capital city of Mongolia. Waste Manage. 28, 435–444.

Taghipour, H., Mosaferi, M., 2009. Characterization of medical waste from hospitals in Tabriz, Iran. Sci. Total Environ. 407, 1527–1535.

Tsakona, M., Anagnostopoulou, E., Gidarakos, E., 2007. Hospital waste management and toxicity evaluation: a case study. Waste Manage. 27, 912–920.

UNEP, 2002. Technical guidelines on the Environmentally Sound Management of Biomedical and Healthcare Waste. Basel Convention, United Nations Environment Programme.

Voudrias, Graikos, 2014. Infectious medical waste management system at the regional level. Journal of Hazardous, Toxic and Radioactive Waste, American Society of Civil Engineers, ISSN 2153-5493/04014020(9).

WHO, 2011. Waste from Health-Care Activities, Fact sheet N°253 <http://www.who.int/mediacentre/factsheets/fs253/en/>.

WHO, 2013. Safe Management of Wastes from Health-Care Activities, second ed.

World Bank, 2012 <http://data.worldbank.org/country/lebanon>.

Yong, Z., Gang, X., Guanxing, W., Zhou, T., Dawei, J., 2009. Medical waste management in China: a case study of Nanjing. Waste Manage. 29 (2009), 1376–1382.