Environmental Engineering and Management Journal

July 2020, Vol. 19, No. 7, 1143-1156
http://www.eemj.icpm.tuiasi.ro/; http://www.eemj.eu

"Gheorghe Asachi" Technical University of Iasi, Romania

QUANTITATIVE ESTIMATION OF HEALTHCARE WASTES GENERATED BY BRAZILIAN HOSPITALS: A LITERATURE REVIEW

Patrícia Albernáz Melo Ribeiro[1], Arthur Couto Neves[2], Marcos Paulo Gomes Mol[2]*

[1]Pontifícia Universidade Católica de Minas Gerais, Av: Dom José Gaspar, 500 Coração Eucarístico - Belo Horizonte – MG, Brazil
[2]Diretoria de Pesquisa e Desenvolvimento. Fundação Ezequiel Dias (FUNED). Conde Pereira Carneiro st. 80, Gameleira. Belo Horizonte/MG. Brazil. CEP 30510-010

Abstract

Poor management of health care waste (HCW) is still recurrent in developing countries, as HCW control thought legislation is recent in many of these countries. One challenging factor that contributes to this is the lack of representative quantification of HCW generation. This kind of indicator is important, principally for hospitals as significant HCW generator, in order to obtain a better waste management. In this context, the aim of this study is proposing a quantitative estimation of HCW generated by Brazilian hospitals, through a literature review. This review compiled published studies that reported rates of HCW generated by Brazilian hospitals. This data was analyzed according to Brazilian location, time period, and hospital specialty. Statistical evaluations were performed using Kruskal-Wallis and Mann-Whitney tests with a significance level of 5% ($\alpha = 0.05$). A total of 49 studies were found within the inclusion criteria, reporting 145 different waste generations by Brazilian hospitals. The mean of generation estimated was 2.97 (2.57 - 3.42) $kg.bed^{-1}.day^{-1}$; 0.99 (0.82 - 1.18) $kg.bed^{-1}.day^{-1}$; 0.14 (0.09 - 0.21) $kg.bed^{-1}.day^{-1}$ for, respectively, total HCW, infectious waste and sharp waste. In the data analysis, it was found significant increase in the number of infectious wastes generated between 2000-2009 and 2010-2019. Generation rate between Brazilian regions showed that Central-West and North values showed a marginal difference. While, HCW generation rates per hospital specialization did not show any significant differences. These new rates, although still within some margins previously reported, shows that the HCW generation in Brazilian hospitals is higher than estimated previously data.

Key words: Brazil, healthcare waste, hospital, quantitative estimation, waste generation

Received: July, 2019; Revised final: January, 2020; Accepted: February, 2020; Published in final edited form: July, 2020

1. Introduction

The healthcare waste (HCW) management, due to the risks involved, represents a challenge for establishments that generate this waste. Many authors report that HCW denotes high risk to public health and for the environment, when incorrectly handled, since they are potentially contaminated by pathogenic microorganisms or chemicals substances (Anvisa, 2006; Ansari et al., 2019; Busnello et al., 2011; Colesanti and Castro, 2007; Shanmugasundaram et al., 2012; WHO, 2018). Among the HCW generators, hospitals are the greatest responsible for waste production when compared to other healthcare facilities. Also, there are aspects that contribute to the growth in HCW generation in hospitals, such as the continuous increase in the complexity of medical care and the high use of disposable materials (Cheng et al., 2009; Hossain and Alam, 2013; Jovanović et al., 2016; Pruss et al., 1999; Sisinno and Moreira, 2005; Stankovic et al., 2008; Teixeira et al., 2018).

According to some authors, segregation at the source of generation could minimize the amount of potentially contaminated materials that would be incorrectly treated or disposed, and consequently, reduce finance expenses (Abdulla et al., 2008; Salkin,

* Author to whom all correspondence should be addressed: e-mail: marcos_mol@yahoo.com.br; Phone: +55 31 33144770; Fax: +55 31 33144770

2001; Tudor et al., 2009). To achieve this minimization, it is mandatory periodical training for employees, principally with those workers who have direct contact with HCW.

As shown by Ali et al. (2007), in many countries the legislation linked to HCW is still a recent progress, in terms of health and environment protection. Therefore, inefficient approaches are still present in phases of implementation and execution of these legislations, and therefore the inadequate handling of this waste can generate negative health and environmental impacts. Usually legislations around the world categorize HCW in non-hazardous waste that has similar characteristics to domestic waste; and hazardous waste, subdivided by WHO (2018) as infectious, pathological, sharps, chemical, pharmaceutical, cytotoxic, and radioactive waste.

In Brazil, the current legislation on HCW is the ANVISA Resolution number 222/2018 (Brasil, 2018), where healthcare waste is classified into five groups: group A (waste with potential presence of infectious agents which, due to their characteristics, may present a risk of infection); group B (wastes containing chemicals that are hazardous to public health or the environment, depending on their characteristics); group C (radioactive waste, regulated by the National Commission of Nuclear Energy); group D (waste which does not pose an infectious, chemical or radiological risks); group E (piercing or scarifying materials such as: needles, scalps, glass ampules, drills, lancets, blades and coverslips, spatulas, blood collection tubes, Petri dishes and lab broken glass or similar). In the literature, there are still few studies proposing a quantitative evaluating of HCW generation in hospitals around the world, and available studies focus on the general information about HCW management in hospitals (Minoglou et al., 2017; Minoglou and Komilis, 2018; Patwary et al., 2009). In the Brazilian context, studies regarding the HCW management and qualitative analysis of the workers perception of HCW in hospitals are more commonly discussed (Pinheiro et al., 2016; Rosa, 2016; Silva et al., 2014; Silva et al., 2015; Spindola and Moura, 2017).

Thus, indicating that in developing countries there is a lack of reliable information about waste generation and availability of appropriated services to treat and dispose these wastes (Mmereki et al., 2016; Naime et at., 2006). In Brazil, healthcare waste generators need to report their estimated quantitative waste generation to the Sanitary Regulatory Agency, but this data is not public available neither is discussed in a larger scientific scenario. Consequently, HCW generation is evaluated only locally, therefore little is known about the country's current state of HCW's generation. Although there are studies discussing the quantitative of HCW generation in Brazilian hospitals, they are still scare in the literature. It is hoped that, through a review in the literature, it will be possible to generate a representative estimation of HCW generation by Brazilian hospitals. Considering the lack of knowledge in this topic, this study aims to present a quantitative estimation of HCW generated in Brazilian hospitals, through a review in the literature compiling published studies that reported rates of HCW generation.

2. Material and methods

A literature review was performed searching for published papers until December of 2019. As main criteria to a study be included, it was considered papers that reported the generation rate of total, infectious and sharps waste in Brazilian hospitals. So, a country estimation of waste generation could be established. The Google Scholar database was utilized in the proposed search for papers, through following keywords: hospital; generation; Brazil; "healthcare waste" OR "medical waste" OR "biological waste". Studies published in English or Portuguese were considered for inclusion in this review.

Those studies found that did not reported any waste generation or the number of hospital beds were discarded. Those papers within the inclusion criteria, the HCW was analyzed according to the category of waste reported. Since some studies that did not clarify the classification of the reported waste, these were considered as the total of HCW being generated in the local of their study. Also, all waste generation found was standardized to $kg.bed^{-1}.day^{-1}$. For those studies that presented the waste generation in liters, it was assumed the density for group A (infectious) and B (chemicals) as 100 $kg.m^{-3}$, group D (similar to domestic) as 150 $kg.m^{-3}$ and group E (sharps) as 200 $kg.m^{-3}$, as suggested by Belo Horizonte (2011). Additionally, it was a customary practice of some studies to combine sharp with infectious wastes and presented only the total of HCW generated. Therefore, as presented by the study, when only infectious waste was reported it was considered as Total HCW generated in the respective hospital.

The gathered data, from the studies within the proposed criteria, were evaluated according to the Brazilian location, the time period, the hospital specialty, the number of beds and the wastes rates. Allowing a descriptive statistical analysis was performed including sample number, arithmetic mean, standard deviation, upper and inferior limit though bootstrap, minimum and maximum value and median. The normality test adopted was Shapiro-Wilk, and the non-parametric Kruskal-Wallis test was used with post-hoc by Nemenyi or Wilcoxon signed-rank test, when necessary. The significance level adopted was 5% ($\alpha = 0.05$). The Software R (version 3.4.5) was used for these analyses. It was evaluated the waste generation per hospital specialty, wastes groups, period before and after 2010, and regional areas.

3. Results

Forty-nine studies met the inclusion criteria, reporting a total of 145 measurements of HCW generation in Brazilian hospitals within 17 different Brazilian states and 35 cities. Those reports were compiled in Table 1.

Table 1. Sources found reporting HCW generation in Brazilian hospitals by region and specialty, ordered by year of study

Source	***Year***	***Region***	***Beds***	***Type***	***HCW generation (kg.bed^{-1}.day^{-1})***		
					Group A	***Group E***	***Total***
Cussiol et al. (2000)	From 2000 to 2009	Southeast	157	General	0.96	NA	2.38
Mattoso and Schalch (2001)	From 2000 to 2009	Southeast	400	General	0.24	0.01	0.97
Schneider et al. (2004)	From 2000 to 2009	South	170	General	0.65	NA	2.56
Da Silva et al. (2005)	From 2000 to 2009	South	5	General	1.84	NA	4.84
Da Silva et al. (2005)	From 2000 to 2009	South	8	General	0	NA	0.57
Da Silva et al. (2005)	From 2000 to 2009	South	9	General	2.56	NA	7.33
Da Silva et al. (2005)	From 2000 to 2009	South	14	General	6.99	NA	11.81
Da Silva et al. (2005)	From 2000 to 2009	South	15	General	0.03	NA	0.31
Da Silva et al. (2005)	From 2000 to 2009	South	16	General	0.03	NA	1.15
Da Silva et al. (2005)	From 2000 to 2009	South	17	General	1.11	NA	1.99
Da Silva et al. (2005)	From 2000 to 2009	South	23	General	0.43	NA	2.61
Da Silva et al. (2005)	From 2000 to 2009	South	32	General	0.23	NA	0.38
Da Silva et al. (2005)	From 2000 to 2009	South	46	General	0.08	NA	5.29
Da Silva et al. (2005)	From 2000 to 2009	South	52	General	0.1	NA	0.19
Da Silva et al. (2005)	From 2000 to 2009	South	55	General	0.01	NA	1.65
Da Silva et al. (2005)	From 2000 to 2009	South	57	General	0.39	NA	0.44
Da Silva et al. (2005)	From 2000 to 2009	South	66	General	0.45	NA	3.79
Da Silva et al. (2005)	From 2000 to 2009	South	71	General	0.49	NA	2.49
Da Silva et al. (2005)	From 2000 to 2009	South	178	General	0.45	NA	0.9
Da Silva et al. (2005)	From 2000 to 2009	South	220	General	0.52	NA	1.34
Da Silva et al. (2005)	From 2000 to 2009	South	252	General	0.63	NA	10.11
Da Silva et al. (2005)	From 2000 to 2009	South	311	General	0.68	NA	1.64
Fonseca et al. (2005)	From 2000 to 2009	Northeast	82	General	0.21	NA	1.09
Fonseca et al. (2005)	From 2000 to 2009	Northeast	121	Maternity	0.22	NA	1.23
Fonseca et al. (2005)	From 2000 to 2009	Northeast	193	General	0.01	NA	0.28
Fonseca et al. (2005)	From 2000 to 2009	Northeast	30	General	0.39	0.04	1.8
Fonseca et al. (2005)	From 2000 to 2009	Northeast	25	Maternity	0.24	NA	1.44
Fonseca et al. (2005)	From 2000 to 2009	Northeast	200	General	0.05	NA	0.45
Fonseca et al. (2005)	From 2000 to 2009	Northeast	150	General	0.09	NA	0.48
Fonseca et al. (2005)	From 2000 to 2009	Northeast	255	General	0.07	NA	0.56
Fonseca et al. (2005)	From 2000 to 2009	Northeast	40	General	0.04	NA	0.59

Fonseca et al. (2005)	From 2000 to 2009	Northeast	18	Hospital Complex	0.86	NA	2.53
Fonseca et al. (2005)	From 2000 to 2009	Northeast	220	General	0.36	NA	5.36
Fonseca et al. (2005)	From 2000 to 2009	Northeast	113	General	0.8	NA	1.24
Caetano and Gomes (2006)	From 2000 to 2009	South	159	Hospital Complex	0.8	0.22	1.6
Leite (2006)	From 2000 to 2009	Southeast	164	General	0.72	NA	3.79
Oliveira (2006)	From 2000 to 2009	Northeast	245	Hospital Complex	0.06	NA	3.98
Coelho (2007)	From 2000 to 2009	Central-West	635	Intensive Care	NA	NA	2.9
Coelho (2007)	From 2000 to 2009	Central-West	204	General	NA	NA	14.17
Coelho (2007)	From 2000 to 2009	Central-West	383	General	NA	NA	4.36
Gil (2007)	From 2000 to 2009	Southeast	201	Hospital Complex	0.07	0.05	1.21
Melo (2007)	From 2000 to 2009	Central-West	289	Teaching Hospital	NA	NA	2.74
Nagashima et al. (2007)	From 2000 to 2009	South	114	Teaching Hospital	1.6	0.13	3.27
Camacho (2008)	From 2000 to 2009	Northeast	314	Teaching Hospital	NA	NA	0.81
Dutra (2009)	From 2000 to 2009	Central-West	400	Hospital Complex	NA	NA	4.27
Tramontini (2009)	From 2000 to 2009	South	522	Hospital Complex	0.54	NA	0.54
Tramontini (2009)	From 2000 to 2009	South	192	Hospital Complex	0.35	NA	8.2
Tramontini (2009)	From 2000 to 2009	South	66	General	0.23	0.01	1.06
Valadares (2009)	From 2000 to 2009	Southeast	25	General	0.23	NA	0.23
Valadares (2009)	From 2000 to 2009	Southeast	45	General	0.48	NA	0.48
Valadares (2009)	From 2000 to 2009	Southeast	97	General	0.37	NA	0.37
Valadares (2009)	From 2000 to 2009	Southeast	76	General	0.23	NA	0.23
Valadares (2009)	From 2000 to 2009	Southeast	62	General	0.14	NA	0.14
Lemos et al. (2010)	From 2000 to 2009	Northeast	180	General	0.01	NA	0.11
Lemos et al. (2010)	From 2000 to 2009	Northeast	437	General	0.1	NA	0.78
Lemos et al. (2010)	From 2000 to 2009	Northeast	76	General	0.43	NA	0.59
Lemos et al. (2010)	From 2000 to 2009	Northeast	248	General	0.45	NA	2.51
Lemos et al. (2010)	From 2000 to 2009	Northeast	238	General	1.36	NA	2.81
Lemos et al. (2010)	From 2000 to 2009	Northeast	276	General	1.35	NA	2.98
Lemos et al. (2010)	From 2000 to 2009	Northeast	306	General	0.9	NA	3.51
Lemos et al. (2010)	From 2000 to 2009	Northeast	370	General	2.49	NA	4.07
Lemos et al. (2010)	From 2000 to 2009	Northeast	220	General	0.44	NA	1.85
Lemos et al. (2010)	From 2000 to 2009	Northeast	416	General	3	NA	4.4
Lemos et al. (2010)	From 2000 to 2009	Northeast	118	General	1.01	NA	4.82

Lemos et al. (2010)	From 2000 to 2009	Northeast	57	General	2.22	NA	5.26
Lemos et al. (2010)	From 2000 to 2009	Northeast	61	General	1.63	NA	4.13
Lemos et al. (2010)	From 2000 to 2009	Northeast	246	General	1.81	NA	6.67
Lemos et al. (2010)	From 2000 to 2009	Northeast	150	General	0.95	NA	9.08
Oliveira (2010)	From 2000 to 2009	Northeast	102	Hospital Complex	0.39	0.07	1.39
Pugliesi (2010)	From 2000 to 2009	Northeast	332	Maternity	0.71	0.05	2.09
Araújo (2011)	From 2010 to 2019	Southeast	462	Intensive Care	0.11	NA	4.16
Ferber (2011)	From 2010 to 2019	South	54	General	0.91	0.1	3.37
Schneider et al. (2019)	From 2010 to 2019	South	170	General	1.44	NA	5.97
Tivirolli et al. (2012)	From 2000 to 2009	Central-West	35	General	NA	NA	2.4
Tivirolli et al. (2012)	From 2000 to 2009	Central-West	240	Intensive Care	NA	NA	4.8
Tivirolli et al. (2012)	From 2000 to 2009	Central-West	343	Intensive Care	NA	NA	4.7
Kopp et al. (2013)	From 2010 to 2019	Southeast	186	Hospital Complex	1.41	NA	4.26
Kopp et al. (2013)	From 2010 to 2019	Southeast	208	General	3.49	NA	6.97
Kopp et al. (2013)	From 2010 to 2019	Southeast	330	Hospital Complex	1.35	0.13	5
Oliveira et al. (2013)	From 2010 to 2019	South	80	Hospital Complex	0.5	0.29	1.98
Valério e Castanheira (2013)	From 2010 to 2019	South	159	Intensive Care	0.99	NA	6.82
Adual et al. (2014)	From 2010 to 2019	Southeast	180	Teaching Hospital	5.34	NA	5.34
Adual et al. (2014)	From 2010 to 2019	Southeast	181	General	1.89	NA	1.89
Adual et al. (2014)	From 2010 to 2019	Southeast	86	General	2.16	NA	2.16
Adual et al. (2014)	From 2010 to 2019	Southeast	180	General	3.05	NA	3.05
Adual et al. (2014)	From 2010 to 2019	Southeast	183	General	1.37	NA	1.37
Adual et al. (2014)	From 2010 to 2019	Southeast	200	Teaching Hospital	2.25	NA	2.25
Adual et al. (2014)	From 2010 to 2019	Southeast	1010	General	2.86	NA	2.86
Ferber (2014)	From 2000 to 2009	South	208	Teaching Hospital	0.6	NA	0.6
Ferber (2014)	From 2000 to 2009	South	208	Teaching Hospital	0.56	NA	0.56
Ferber (2014)	From 2010 to 2019	South	208	Teaching Hospital	0.53	NA	0.53
Ferber (2014)	From 2010 to 2019	South	208	Teaching Hospital	0.47	NA	0.47
Ferber (2014)	From 2010 to 2019	South	208	Teaching Hospital	0.5	NA	0.5
Ferber (2014)	From 2010 to 2019	South	208	Teaching Hospital	0.51	NA	4.6
Campos (2015)	From 2010 to 2019	Southeast	337	Hospital Complex	0.89	0.89	2.97
Campos (2015)	From 2010 to 2019	Southeast	125	General	0.3	0.05	1.08
Da Silva et al. (2015)	From 2010 to 2019	South	360	Maternity	1.87	NA	5.3

Da Silva et al. (2015)	From 2010 to 2019	South	360	Maternity	2.05	NA	6.33
Da Silva et al. (2015)	From 2010 to 2019	South	360	Maternity	2.14	NA	6.83
Da Silva et al. (2015)	From 2010 to 2019	South	360	Maternity	2.25	NA	7.04
Gomes (2015)	From 2010 to 2019	North	279	Hospital Complex	0.73	NA	1.04
Gomes (2015)	From 2010 to 2019	North	279	Hospital Complex	0.82	NA	1.2
Gomes (2015)	From 2010 to 2019	North	279	Hospital Complex	1.08	NA	1.53
Gomes (2015)	From 2010 to 2019	North	279	Hospital Complex	1.12	NA	1.68
Gomes (2015)	From 2010 to 2019	North	279	Hospital Complex	0.95	NA	1.46
Maders and Cunha (2015)	From 2010 to 2019	North	101	Intensive Care	2.2	0.24	6.99
Moreira et al. (2015)	From 2010 to 2019	Southeast	231	General	0.03	0.01	0.14
André et al. (2016)	From 2010 to 2019	Southeast	704	Teaching Hospital	NA	NA	7.33
André et al. (2016)	From 2010 to 2019	Southeast	25	Teaching Hospital	NA	0.08	6
André et al. (2016)	From 2010 to 2019	Southeast	295	General	NA	0.03	5.91
André et al. (2016)	From 2010 to 2019	Southeast	95	Teaching Hospital	1.81	NA	4.32
André et al. (2016)	From 2010 to 2019	Southeast	50	General	1.37	0.31	9.21
André et al. (2016)	From 2010 to 2019	Southeast	158	Teaching Hospital	3.44	0.28	6.94
André et al. (2016)	From 2010 to 2019	Southeast	130	Teaching Hospital	1.32	0.09	4.15
André et al. (2016)	From 2010 to 2019	Southeast	212	Teaching Hospital	0.96	NA	4.11
André et al. (2016)	From 2010 to 2019	Southeast	13	General	1.77	0.58	8.86
André et al. (2016)	From 2010 to 2019	Southeast	39	Maternity	0.77	0.05	3.6
André et al. (2016)	From 2010 to 2019	Southeast	41	General	0.52	0.11	4.54
Rosa (2016)	From 2010 to 2019	South	16	Intensive Care	0.47	NA	0.47
Rosa (2016)	From 2010 to 2019	South	131	Hospital Complex	0.49	NA	3.52
Luczynski et al. (2018)	From 2010 to 2019	North	236	Hospital Complex	0.57	NA	1.64
Bastos (2017)	From 2010 to 2019	North	100	Intensive Care	0.28	NA	1.18
Oliveira (2017)	From 2010 to 2019	Southeast	180	Intensive Care	0.56	NA	0.58
Oliveira (2017)	From 2010 to 2019	Southeast	180	Intensive Care	0.66	NA	0.68
Oliveira (2017)	From 2010 to 2019	Southeast	180	Intensive Care	0.86	NA	0.88
Dias et al. (2017)	From 2010 to 2019	South	307	Hospital Complex	0.83	0.1	4.15
Franzosi (2017)	From 2010 to 2019	South	60	General	0.61	0.13	1.25
Franzosi (2017)	From 2010 to 2019	South	20	General	1.07	0.04	1.76
Franzosi (2017)	From 2010 to 2019	South	34	General	1.35	0.07	3.11
Franzosi (2017)	From 2010 to 2019	South	43	General	0.44	0.03	0.82

Franzosi (2017)	From 2010 to 2019	South	90	Hospital Complex	3.45	0.13	5.14
Franzosi (2017)	From 2010 to 2019	South	37	General	1.05	0.02	1.31
Spindola and Moura (2017)	From 2010 to 2019	South	1327	General	1.26	NA	4.51
Casado (2018)	From 2010 to 2019	South	54	General	0.09	0.03	0.54
Kist et al. (2018)	From 2010 to 2019	Southeast	131	General	NA	NA	0.47
Pereira et al. (2018)	From 2010 to 2019	North	300	Teaching Hospital	NA	NA	0.76
Urioste et al. (2018)	From 2010 to 2019	Southeast	200	General	1.5	NA	1.5
Ferber et al. (2019)	From 2010 to 2019	South	54	Hospital Complex	1.21	NA	4.12
Ferber et al. (2019)	From 2010 to 2019	South	178	Teaching Hospital	0.31	NA	1.82
Ishida and Almeida (2019)	From 2010 to 2019	North	NA	General	0.4	NA	0.4
Ishida and Almeida (2019)	From 2010 to 2019	North	NA	General	0.2	NA	0.2
Ishida and Almeida (2019)	From 2010 to 2019	North	NA	General	0.16	NA	0.16
Ishida and Almeida (2019)	From 2010 to 2019	North	NA	General	3.01	NA	3.01
Message (2019)	From 2010 to 2019	South	54	Teaching Hospital	0.39	0.09	3.45
Santos et al. (2019)	From 2010 to 2019	Southeast	509	Teaching Hospital	0.82	0.15	4.09

Legend: Group A: infectious waste according to BRASIL (2018); Group E: sharp waste according to BRASIL (2018); NA: Not available

The mean of total HCW generation was 2.97 (2.57 - 3.42) kg.bed^{-1}.day^{-1} considering all 145 hospitals found in this review. As for infectious wastes, the mean was 0.99 (0.82 - 1.18) kg.bed^{-1}.day^{-1} in 131 hospitals, and sharps wastes showed the mean of 0.14 (0.09 - 0.21) kg.bed^{-1}.day^{-1} for 33 hospitals. The difference in the number of hospitals for each HCW category is due to the lack of details reported in the studies available in the literature.

Most of the studies found were performed between 2000 to 2009. For this period, the mean of the total generation of HCW was 2.75 (2.16 - 3.40) kg.bed^{-1}.day^{-1} for 75 hospitals (Table 2). On the other hand, studies after 2010 presented a mean of total HCW generation 3.20 (2.68 - 3.80) kg.bed^{-1}.day^{-1} for 70 hospitals. For infectious wastes, generation range for period of 2000 to 2009 was 0.73 (0.51 - 1.00) kg.bed^{-1}.day^{-1} for 66 hospitals, while for 2010 to 2019 the range was 1.26 (1.01 - 1.51) kg.bed^{-1}.day^{-1} for 65 hospitals. Sharps objects had fewer studies reported and the waste generation range was 0.08 (0.03 - 0.13) for eight older studies and 0.16 (0.10 - 0.24) for 25 more recent studies. Table 2 presented a quantitative description of HCW per period.

It was also noted a generation increase over the years for all waste groups. However, a statistical significant difference between the periods was only observed for infectious waste.

We also evaluated the HCW generation by waste group according to each type of hospital main service. Statistical differences were found (p value>0.05) only for sharps generation, as showed in Table 3. The range of HCW generation by hospital specialty was: General 2.82 (2.23 - 3.51) kg.bed^{-1}.day^{-1} in 83 studies; Hospital Complex 2.88 (2.16 - 3.64) kg.bed^{-1}.day^{-1} in 22 studies; Intensive Care 3.11 (1.80 - 4.50) kg.bed^{-1}.day^{-1} in 11 studies; Maternity 4.23 (2.71 - 5.70) kg.bed^{-1}.day^{-1} in eight studies; Teaching 3.08 (2.22 - 4.01) kg.bed^{-1}.day^{-1} in 21 studies.

The range of infectious waste generation according to the hospital specialization was: General 0.95 (0.73 - 1.23) kg.bed^{-1}.day^{-1} in 78 studies; Hospital Complex 0.88 (0.64 - 1.22) kg.bed^{-1}.day^{-1} in 21 studies; Intensive Care 0.77 (0.41 - 1.24) kg.bed^{-1}.day^{-1} in eight studies; Maternity 1.28 (0.75 - 1.85) kg.bed^{-1}.day^{-1} in eight studies; Teaching 1.34 (0.80 - 2.03) kg.bed^{-1}.day^{-1} in 16 studies. While for sharps, few studies reported the waste generation for this specific group. The generation per hospital specialty was: General 0.10 (0.04 - 0.18) kg.bed^{-1}.day^{-1} in 16 studies; Hospital Complex 0.24 (0.10 - 0.45) kg.bed^{-1}.day^{-1} in eight studies; Intensive Care 0.24 kg.bed^{-1}.day^{-1} for only one study; Maternity 0.05 kg.bed^{-1}.day^{-1} in two studies; Teaching 0.14 (0.10 - 0.20) kg.bed^{-1}.day^{-1} in six studies. It was found a marginal difference on sharps generation between the specialties General and Hospital Complex.

In this review, all Brazilian regions were represented, as presented in Table 4. Still, most of the hospitals were in the Northeast and South regions. A marginal statistical difference in HCW generation was found between the Brazilian regions. The waste generation range per regions was: Central-West 5.04 (3.21 - 7.72) kg.bed^{-1}.day^{-1} for eight hospitals; North

1.64 (0.89 - 2.62) kg.bed^{-1}.day^{-1} for 13 hospitals; Northeast 2.55 (1.82 - 3.29) kg.bed^{-1}.day^{-1} for 31 hospitals; South 3.07 (2.40 - 3.83) kg.bed^{-1}.day^{-1} for 53 hospitals; and Southeast 3.16 (2.36 - 3.99) kg.bed^{-1}.day^{-1} for 40 hospitals. These results were also presented in Fig. 1 where a Brazilian map indicated the healthcare waste generation per region.

On the other hand, none significant differences were found for infectious waste and sharps. The infectious waste range generation per region was: Central-West 1.96 kg.bed^{-1}.day^{-1} for one hospital; North 0.97 (0.65 - 1.36) kg.bed^{-1}.day^{-1} for eight hospitals; Northeast 1.06 (0.76 - 1.39) kg.bed^{-1}.day^{-1} for 44 hospitals; South 1.51 (0.81 - 2.62) kg.bed^{-1}.day^{-1} for 46 hospitals; Southeast 1.77 (1.04 - 2.69) kg.bed^{-1}.day^{-1} for 22 hospitals. The generation of sharps wastes per region was: Central-West 0.30 kg.bed^{-1}.day^{-1} for one hospital; North 0.25 kg.bed^{-1}.day^{-1} for one hospital; Northeast 0.14 (0.07 - 0.22) kg.bed^{-1}.day^{-1} for 11 hospitals; South 0.09 (0.05 - 0.13) kg.bed^{-1}.day^{-1} for 14 hospitals; Southeast 0.07 (0.01 - 0.15) kg.bed^{-1}.day^{-1} for three hospitals.

Table 2. Quantitative description of waste generation found per period (kg bed^{-1}day^{-1})

Group	*Period*	*n*	*Mean*	*S.D.*	*Min.*	*Median*	*Max.*	*p-Value*
Total	From 2000 to 2009	75	2.75	2.79	0.11	1.85	4.03	0.09
	From 2010 to 2019	70	3.20	2.38	0.14	2.99	4.60	
A	From 2000 to 2009	66	0.73	1.03	0.00	0.45	0.86	**<0.01**
	From 2010 to 2019	65	1.26	1.02	0.03	0.96	1.77	
E	From 2000 to 2009	8	0.07	0.07	0.01	0.05	0.10	0.14
	From 2010 to 2019	25	0.16	0.20	0.01	0.10	0.15	

Legend: n: sample number; S.D.: standard deviation; Min.: minimum; Max.: maximum; p-Value for Mann Whitney test; bold: value below 0.05 indicating significant difference; Group A: infectious waste according to BRASIL (2018); Group E: sharp waste according to BRASIL (2018)

Table 3. HCW generation per hospital specialization (kg bed^{-1}day^{-1})

Group	*Specialty*	*n*	*Mean*	*S.D.*	*Min.*	*Median*	*Max.*	*p-Value*
Total	General	83	2.817	2.886	0.11	1.85	14.17	0.26
	Hospital Complex	22	2.882	1.859	0.54	2.255	8.2	
	Intensive Care	11	3.105	2.516	0.47	2.9	6.99	
	Maternity	8	4.232	2.449	1.23	4.45	7.04	
	Teaching Hospital	21	3.078	2.228	0.47	3.27	7.33	
A	General	78	0.945	1.11	0	0.505	6.99	0.33
	Hospital Complex	21	0.88	0.697	0.06	0.82	3.45	
	Intensive Care	8	0.766	0.646	0.11	0.61	2.2	
	Maternity	8	1.281	0.879	0.22	1.32	2.25	
	Teaching Hospital	16	1.338	1.363	0.31	0.71	5.34	
E	General	16	0.098	0.149	0.01	0.04	0.58	**0.04**
	Hospital Complex	8	0.235	0.276	0.05	0.13	0.89	
	Intensive Care	1	0.24	NA	0.24	0.24	0.24	
	Maternity	2	0.05	0	0.05	0.05	0.05	
	Teaching Hospital	6	0.137	0.075	0.08	0.11	0.28	

Legend: n: sample number; S.D.: standard deviation; Min.: minimum; Max.: maximum; Group A: infectious waste according to BRASIL (2018); Group E: sharp waste according to BRASIL (2018)

Table 4. Quantitative description of HCW generation found per regional (kg bed^{-1}day^{-1})

Group	*Region*	*n*	*Mean*	*S.D.*	*Min.*	*Median*	*Max.*	*p-Value*
Total	Central-West	8	5.04	3.81	2.40	4.32	14.17	**0.06**
	North	13	1.64	1.78	0.16	1.20	6.99	
	Northeast	31	2.55	2.15	0.11	1.85	9.08	
	South	53	3.07	2.73	0.19	1.99	11.81	
	Southeast	40	3.16	2.51	0.14	2.92	9.21	
A	Central-West	NA	NA	NA	NA	NA	NA	0.10
	North	12	0.96	0.85	0.16	0.78	3.01	
	Northeast	30	0.76	0.80	0.01	0.44	3.00	
	South	53	0.94	1.11	0.00	0.54	6.99	
	Southeast	36	1.29	1.18	0.03	0.93	5.34	
E	Central-West	NA	NA	NA	NA	NA	NA	0.45
	North	1	0.24	NA	0.24	0.24	0.24	
	Northeast	3	0.05	0.02	0.04	0.05	0.07	
	South	14	0.10	0.08	0.01	0.10	0.29	
	Southeast	15	0.19	0.25	0.01	0.09	0.89	

Legend: n: sample number; S.D.: standard deviation; Min.: minimum; Max.: maximum; Group A: infectious waste according to BRASIL (2018); Group E: sharp waste according to BRASIL (2018)

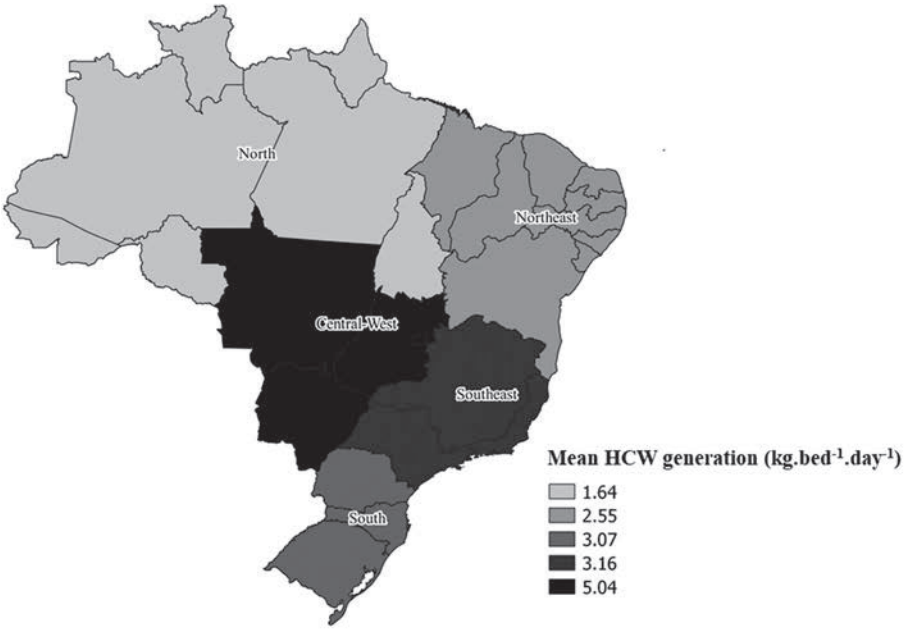

Fig. 1. Brazilian map presenting the healthcare waste generation per region

In order to clarify the marginal statistical difference, found in Table 4, post-hoc Nemenyi test was done and revealed a significant difference between North and Central-West, as shown in Table 5.

Table 5. p-Value for the post-hoc Nemenyi test between HCW generations per region

Region	***Central-West***	***North***	***Northeast***	***South***
North	**0.03**	-	-	-
Northeast	0.19	0.68	-	-
South	0.32	0.33	0.97	-
Southeast	0.43	0.27	0.92	1.00

4. Discussions

In general, the generation of HCW is related to some factors such countries' economic development, availability and complexity of the needed medical attention, number of patients, number of beds, types of medical facilities (Schneider et al., 2001). Usually in developed countries, a higher rate of HCW generation is expected due to the accessibility of more technologies, where there has been an increased usage of disposable and individual use items in medical care to minimalize risk of infection (Vaccari et al., 2018).

The generation presented by Andre et al. (2016) shows an average generation from 7 to 10 kg.bed^{-1}.day^{-1} for North America, 3 to 6 kg.bed^{-1}.day^{-1} for Western Europe and 1 to 4.5 kg.bed^{-1}.day^{-1} for Latin America. Specifically, for Brazil, in a study by Formaggia (1995), the estimation found was 1.20 to 3.50 kg.bed^{-1}.day^{-1}. In this study, the HCW generation by Brazilian hospitals was 2.97 (2.57 - 3.42), within the previously margin for Latin America and resembling the high limit according to Formaggia (1995). Within Latin America, few studies discussed the HCW generation tax in hospitals. In an older Uruguayan report presented in a study by Ramírez et al. (2017), it was possible to see that the HCW tax estimated for Brazil, is within the generation margin, as for Venezuela (2.56-3.71 kg.bed^{-1}.day^{-1}), Argentina (0.82-4.2 kg.bed^{-1}.day^{-1}) and Uruguay (3 – 4.5 kg.bed^{-1}.day^{-1}), whereas for Chile (0.97 – 1.21 kg.bed^{-1}.day^{-1}) and Peru (1.6 – 6 kg.bed^{-1}.day^{-1}).

The waste generation tax found for Brazil in our study differed from those reported in Asia, while in Iran ranged from 2.3 until 4.45 kg.bed^{-1}.day^{-1} considering studies by Arab et al. (2008) and Askarian et al. (2004). Brazilian HCW generation results was still higher than the HCW generation reported in China (0.59 - 0.79 kg.bed^{-1}.day^{-1}), India (0.08 - 1.04 kg.bed^{-1}.day^{-1}) and Turkey (0.28 - 0.82 kg.bed^{-1}.day^{-1}) (Ali et al. 2017; Hadipour et al. 2014; Onursal 2003; Uysal 2004; Zhang et al. 2013).

The HCW generation in Brazil is similar to few European countries as United Kingdom and France with 3.3 kg.bed^{-1}.day^{-1}, yet lower than Norway and Spain, with 3.9 kg.bed^{-1}.day^{-1} and 4.4 kg.bed^{-1}.day^{-1}, respectively (Akbolat et al. 2011; Bdour et al. 2007).

Also, when considering African countries, the Brazilian HCW generation tax is above some reports such Jordan (0.88-1.36 kg.bed^{-1}.day^{-1}), Ethiopia (average of 1.23 kg.bed^{-1}.day^{-1}), Egypt (0.7-1.7 kg.bed^{-1}.day^{-1}) and Sudan (average of 0.87 kg.bed^{-1}.day^{-1}) (Hayleeyesus and Cherinete 2016; Minoglou et al. 2017; Qdai et al. 2007; Saad 2013).

Evaluating the HCW per periods, from 2000 to 2009 and 2010 to 2019, it was possible to observe that waste generation for sharps and total HCW did not present a significant statistical difference between the periods. However, a significant variation was found for infectious waste demonstrating an increase in this type of waste generation over the years. Yet, this variation was expected since the growth in population, leads to more healthcare establishments and, also, an

increase in usage of disposable medical products (Arab et al. 2008; Taghipour and Mosaferi, 2009). On the other hand, this increasing of infected wastes may suggest a low efficacy of HCW segregation, as presented by Barbosa and Mol (2018) that analyses HCW management and the reason for indicator variance. In addition, sharps generation was higher over the period 2010-2019. This increased value of sharps wastes may be explained by improvements in waste segregation in the hospitals along the years, due to the growth in discussions about HCW management in Brazil in the last decade (Aduan et al., 2014; Alves et al., 2014; Moreira and Günther, 2013; Vieira et al., 2009).

The lack of improvement in the waste segregation may be attributed to the scarce knowledge about the health and environmental impacts correlated to HCW, nonexistence of a waste management and disposal systems, abstinence of training, that could lead a proper waste management, and also deficient financial and human resources, possibility, due to the low priority given to this topic (WHO, 2018).

The HCW according to the hospitals specialties in this study were: General 2.82 (2.23 - 3.51) kg.bed^{-1}.day^{-1}; Hospital Complex 2.88 (2.16 - 3.64) kg.bed^{-1}.day^{-1}; Intensive Care 3.11 (1.80 - 4.50) kg.bed^{-1}.day^{-1}; Maternity 4.23 (2.71 - 5.70) kg.bed^{-1}.day$^{-1;}$ Teaching 3.08 (2.22 - 4.01) kg.bed^{-1}.day^{-1}.

When discussing HCW generation rates by hospital specialty, according to Pruss (1999), a teaching hospital in the EUA generates from 4.10 to 8.70 kg.bed^{-1}.day^{-1}, higher than the generation found in this study, 3.08 (2.22 - 4.01) kg.bed^{-1}.day^{-1}, while in the general hospital, the data presented by Pruss (1999) was from 2.1 to 4.2 kg.bed^{-1}.day^{-1}, similar to Brazilian data, 2.82 (2.23 - 3.51) kg.bed^{-1}.day^{-1}.

Founds for Brazilian HCW generation by hospitals were similar to the reference values presented by WHO for general hospital. On the other hand, teaching hospitals stayed near the lower limit of WHO estimation. The amount of HCW generated by health services changes according to the characteristics of the establishment. Therefore, differences between the studied hospitals were expected, once between the hospitals found there had different specialties, number of bed and complexity of attendance (André et al., 2016).

In other studies, such Askarian et al. (2004), they presented data on hospital waste generation in several regions of the world, citing variations ranging from 0.67 to 21.33 kg.bed^{-1}.day^{-1}. For teaching hospitals in Iran, the average HCW generation reported was 4.51 kg.bed^{-1}.day^{-1} above the generation found in Brazil 2.97 (2.57-3.42). While for non-teaching hospitals, the mean HCW generation rate was 3.59 kg.bed^{-1}.day^{-1} below only the tax found for intensive care found in this study.

These data stimulate the discussion on hospital waste management and health services in general. Practical economic interests further enhance this discussion. Bencko et al. (2003) discussing the situation of the Prague General Hospital, showing that the cost of disposing of common waste is € 75 tonne^{-1}, while the cost for treating and disposing of hospital waste is € 260.tonne^{-1}. These authors assure that this difference is significant in the institution's budget and justifies the establishment of future challenges to improve the treatments in the institution. In Brazil, HCW treatment by incineration is presented as USD 0.76kg^{-1}, while landfill destination for urban solid wastes represented USD 0.15kg^{-1} (Barbosa and Mol, 2018). Costs related to annual overall waste management were USD 2.36 kg^{-1} in Italy, as presented by Vaccari et al. (2018), USD 3.93 kg^{-1} to dangerous wastes and USD 1.14 kg^{-1} to non-dangerous wastes. According to Miyazaki and Une (2005) in Japan, infectious waste is not collected and transported by the municipal government, therefore, medical institutions are responsible for the expense, so they must hire specific company authorized for the treatment. Prices for treatment of these wastes are estimated between USD 0.9 to 1.3 kg^{-1}.

It is noteworthy that deficiencies in the management of HCW can occur in the practice of management due to inadequate segregation, which contributes to the increase for waste. The common waste, when packed with the contaminated materials, should be also considered as contaminated, increasing unnecessarily the amount of waste to be treated and also increases the risks for handling the wastes.

Monreal (1993) stated that, in Brazil, the generation of HCW kg.bed^{-1}.dia^{-1}, with 15 to 20% of this total representing infectious wastes. This panorama reveals the need to implement and follow the regulations that establish HCW management. While in this review, the average generation was 2.97 kg.bed^{-1}.day^{-1}, with 21% of infectious waste, indicating an even more worrisome scenario.

The usual reasons for failure in the HCW management is lack of concern associated to HCW hazardous waste, inappropriate training for proper waste management, lack of waste management and disposal, insufficient financial and human resource, and low priority given to the topic, according to WHO (2011) and Hakim et al. (2012). Harhay et al. (2009) emphasize that limited financial resources and lack of definition of who is responsible for managing HCW are the most common reasons identified as responsible for gaps and failures in the sector in low and middle-income countries.

It is noteworthy that deficiencies in the HCW management can occur in the practice of management due to inadequate segregation, which contributes to increases for waste. The common waste, when segregated appropriately, may be sent to recyclable process. But usually this deficiency is not seen by HCW managers since they, usually, do not have data on the expected waste generation in hospitals. This lack of information makes even harder the identification of improper waste management, once, there are few studies showing a standard of what should be expected and could be followed to find a flaw in the flow of waste handling, from its generation to is final disposal.

5. Limitations

Our study presented a literature review and, due to this methodology, we do not had access to information about the real condition of waste segregation in studied hospitals. Therefore, our results represented a HCW variation according to secondary data, and it is necessary to consider that each study may be adopted different measurement methods for wastes quantification. This new estimating restricts the margins previously used in the literature, although is this within the range estimate by organizations as WHO.

6. Conclusions

Since there is a lack of data available about HCW generation in Brazilian hospitals, the evaluation we proposed generated a new estimation of data that could be useful for proposition of laws focused in the real management situation per hospital specialty and per Brazilian region. HCW waste quantity monitoring process is recommended to control the financial expenses in the waste management process, as improper HCW segregation represent unnecessary high expense for hospitals. This emphasize the HCW management challenge, not only to hospitals but also for the governmental agencies responsible to legislate over the correct handling, treatment, and disposition of hazardous waste.

Is important to highlight that region, period, and hospital specialty may influence the HCW generation rates and should be analyzed in detail in future studies. This kind of study should be done frequently and including all regions around the world looking for improve the implemented HCW management systems.

Acknowledgements

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: Financial support provided by Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG) and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq)

References

Abdulla F., Abu Qdais H., Rabi A., (2008), Site investigation on medical waste management practices in Northern Jordan, *Waste Managemen*t, **28**, 450-458.

Aduan S.A., Braga F.D.S., Zandonade E., Salles D., Cussiol N.A.D.M., Lange L.C., (2014), Evaluation of healthcare wastes service of group A in the hospitals of Vitória (ES), Brazil, *Engenharia Sanitária e Ambienta,* (in Portuguese), **19**, 133-141.

Akbolat M., Cemile D.E.D.E., Oguz I.S.I.K., Saglam H., (2011), Medical waste management practices in Turkey: A case study in Sakarya, *Pakistan Journal of Medical Sciences*, **27**, 892-895.

Ali M., Wang W., Chaudhry N., Geng Y., (2017), Hospital waste management in developing countries: A mini review, *Waste Management and Research*, **35**, 581-592.

Alves S.B., Souza A.C., Tipple A.F., Rezende K.C., Resende F.R., Rodrigues E.G., Pereira M.S., (2014), The reality of waste management in primary health care units in Brazil, *Waste Management and Research*, **32**, 40-47.

André S.C.D.S., Veiga T.B., Takayanagui A.M.M., (2016), Generation of Medical Waste in hospitals in the city of Ribeirão Preto (SP), Brazil, *Engenharia Sanitária e Ambiental,* (in Portuguese), **21**, 123-130.

Ansari M., Ehrampoush M.H., Farzadkia M., Ahmadi E., (2019), Dynamic assessment of economic and environmental performance index and generation, composition, environmental and human health risks of hospital solid waste in developing countries; A state of the art of review, *Environment International*, **132**, 1050732-105073.

ANVISA, Agência Nacional de Vigilância Sanitária, (2006), *Healthcare Waste Management Handbook,* Série A: Normas e Manuais Técnicos, Ministério da Saúde (in Portuguese), Brasília, Brazil.

Arab M., Baghbani R.A., Tajvar M., Pourreza A., Tajvar M., Omrani G., Mahmoudi M., (2008), The assessment of hospital waste management: a case study in Tehran, *Waste Management and Research*, **26**, 304-308.

Askarian M., Vakili M., Kabir G., (2004), Hospital waste management status in university hospitals of the Fars Province, Iran, *International Journal of Environmental Health Research*, **14**, 295-305.

Barbosa F.C.L., Mol M.P.G., (2018), Proposal of indicators for healthcare waste management: Case of a Brazilian public institution, *Waste Management and Research*, **36**, 934-941.

Bastos A., (2017), *Cost variation associated with the infectious solid waste management process in a general hospital*, MSc Thesis, Federal University of Bahia, Palmas, Brazil.

Bdour A., Altrabsheh B., Hadadin N., Al-Shareif M., (2007), Assessment of medical wastes management practice: a case study of the northern part of Jordan, *Waste Management*, **27**, 746-759.

Belo Horizonte, (2011), *Guidance Regulation Manual for the Construction of Health Service Waste Management Plan Monitoring, Evaluation and Control Indicators,* Prefeitura Municipal de Belo Horizonte, Belo Horizonte, (in Brazilian Portuguese), Brazil.

Bencko V., Kapek J., Vins O., (2003), Hospital waste treatment and disposal in the general University Hospital - current situation and future challenges, *Indoor and Built Environment*, **12**, 99-104.

Brasil, (2018), Regulates Good Healthcare Waste Management Practices, Ministério da Saúde, Agência Nacional de Vigilância Sanitária - ANVISA, Diário Oficial.

Busnello G., França R., Silva P., (2011), *Diagnosis of Solid Waste Management of Health Services in the Basic Units of the Municipality of Chapecó-SC*, 26 Cong. Brasileiro de Engenharia Sanitária Ambiental, (in Brazilian Portuguese), Porto Alegre, Brazil.

Caetano M.O., Gomes L.P., (2006), Proposal of a health services waste management plan for the Hospital Beneficiência Portuguesa, *Estudos Tecnológicos em Engenharia* (in Portuguese), **2**, 99-112.

Camacho C.L., (2008), *Environmental management in public health: a study on the environmental perception of solid waste management of health services, from the servers of the Hospital Universitário Onofre Lopes, Rio Grande do Norte*, MSc Thesis, Federal University of Rio Grande do Norte, Natal, Brazil.

Campos F.D.S.P., (2015), *Evaluation of the health services waste management system*, MSc Thesis, University of Nove de Julho, São Paulo, Brazil.

Casado G.W., (2018), *Solid waste management plan for health services at the Municipal Hospital of São Pedro do Sul – RS: a case study*, MSc Thesis, Universidad Federal University of Rio Grande do Sul, Porto Alegre, Brazil.

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 Management*, **29**, 440-444.

Coelho N.M.G.P., (2007), *Healthcare waste management: Management of potentially infectious and piercing-cutting waste in child, adult and emergency hospital admissions units of public hospitals in the Federal District,* MSc Thesis, University of Brasília, Brasília, Brazil.

Colesanti N., Castro M., (2007), *Subsidies for the Management of Health Services Waste in Medium-Sized Municipalities: a Case Study from the Municipality of Araraquara-SP,* Simp. Inter. em Gestão Ambiental e Saúde (in Portuguese), São Paulo, Brazil.

Cussiol N. A. D. M., Lange L. C., Ferreira J. A., (2000), *Rate of Waste Generation of Health Services in a Pediatric Hospital,* 21º Congresso Brasileiro de Engenharia Sanitária e Ambiental (in Portuguese), João Pessoa, Brazil, vol. 21, 1-8.

Cussiol N.A., Lange L.C., (2014), Evaluation of waste from health services of Group A in hospitals in Vitória, Brasil, Engenharia Sanitária e Ambiental (in Portuguese), **19**, 133-141.

Da Silva C.E., Hoppe A.E., Ravanello M.M., Mello N., (2005), Medical wastes management in the South of Brazil, *Waste Management*, **25**, 600-605.

Da Silva C.S.D.S., Kohl C.A., Carneiro A.P., (2015), *Diagnosis of Waste Management of Health Service in Porto Alegre/RS,* VI Congresso Brasileiro de Gestão Ambiental, (in Brazilian Portuguese), Porto Alegre, Brazil.

Dias G.L., Sarturi F., Camponogara S., de Lima S.B.S., Lopes L.F.D., Trevisan C.M., (2017), Analysis of the medical waste production rate in a teaching hospital, *Revista de Pesquisa: Cuidado é Fundamental Online* (in Portuguese), **9**, 92-98.

Dutra L.M.A., (2009), *Study on solid waste management of health services at the Regional Hospital of Asa Norte,* MSc Thesis, University of Brasília, Brazil.

Ferber M.C.S., (2011), *Evaluation of the solid waste management system of the health service of the Hospital Institute of Medicine and Surgery of Paraná-IMPC,* MSc Thesis, Federal University of Santa Catarina, Florianópolis, Brazil.

Ferber M.C.S., (2014), *Management of solid waste of health services in UFSC university hospital: monitoring and proposition of indicators of quality of services,* MSc Thesis, Federal University of Santa Catarina, Florianópolis, Brazil.

Ferber M.S., de Castilhos Júnior A. B., Pereira L.C., (2019), *Preliminary Assessment of Solid Waste Management of Health Services at the Medicine and Surgery Institute of Paraná and at the UFSC University Hospital*, XXXI Cong. Centro-Americano de Engenharia Sanitária e Ambiental, (in Portuguese), Panamá, vol. 31, 1-8.

Fonseca E., Nóbrega C.C., Oliveira A.G.D., (2005), *Production and Rate of Solid Waste Generation of health services of hospitals in João Pessoa-Paraíba,* Cong. Brasileiro de Engenharia Sanitária e Ambiental, (in Portuguese), **23**, 1-8.

Formaggia D.M.E., (1995), *Healthcare Waste,* In: *Healthcare Waste Management*, CETESB, São Paulo, Brazil, 3-13.

Franzosi F., (2017), *Diagnosis of solid health waste management in hospitals in the extreme west of the state of Santa Catarina*, MSc Thesis, University of Santa Cruz do Sul, Brazil.

Gil T.N.L., (2007), *Qualitative and quantitative characterization of health care waste generated in the Santa Casa de Misericórdia Brotherhood of São Carlos, SP*, MSc Thesis, University of São Paulo, São Paulo, Brazil.

Gomes J.D.S., (2015), *Between "residue", risks and waste: perspectives and challenges in waste management in public hospitals in the State of Pará,* PhD Thesis, Federal University of Pará, Brazil.

Hadipour M., Saffarian S., Shafiee M., Tahmasebi S., (2014), Measurement and management of hospital waste in southern Iran: a case study, *Journal of Material Cycles and Waste Management*, **16**, 747-752.

Hakim S.T., Tayyab S.M.H., Shafiq A., Nadeem S.G., (2012), Reuses of syringes: a social crime related to health care waste management, *African Journal of Microbiology Research*, **6**, 2272-2276.

Harhay M.O., Halpern S.D., Harhay J.S., Olliaro P.L., (2009), Health care waste management: a neglected and growing public health problema worldwide, *Tropical Medicine and International Health*, **14**, 1414-1417.

Hayleeyesus S.F., Cherinete W., (2016), Healthcare waste generation and management in public healthcare facilities in Adama, Ethiopia, *Journal of Health and Pollution*, **6**, 64-73.

Hossain M., Alam O., (2013), *A Deeper Look into the Inner Factors Associated to Healthcare Waste Management in Chittagong–the Commercial Capital of Bangladesh*. Proc. of Fourteenth Int. Waste Manag. and Landfill Symp., Cagliari, Italy.

Ishida C.S.P., da Silva Almeida A.A., (2019), Challenges in the implementation of the health services residual management plan in hospitalsm (in Portuguese), *Revista Ibero-Americana de Ciências Ambientais,* **10**, 110-130.

Jovanović V., Manojlović J., Jovanović D., Matic B., Đonović N., (2016), Management of pharmaceutical waste in hospitals in Serbia-challenges and the potential for improvement, *Indian Journal of Pharmaceutical Education and Research*, **50**, 695-702.

Kist L.T., da Rosa F.R., Moraes J.A.R, Machado E.L., (2018), Diagnosis of Hospital Waste Management in Vale Do Rio Pardo-Rio Grande Do Sul, Brazil (in Portuguese), *Revista de Gestão Ambiental e Sustentabilidade,* **7**, 554-569.

Kopp M.D.P., Araujo C.A.S., Figueiredo K.F., (2013), Management of hospital solid waste: a case study in hospitals in Rio de Janeiro and São Paulo (in Portuguese), *Gestão Contemporânea,* **13**, 71-95.

Leite K.F.D.S., (2006), *The hospital organization and waste management of a private institution,* MSc Thesis, University of São Paulo, Brazil.

Lemos K.I.L., Silva M.G.C.D., Pinto F.J.M., (2010), Waste production in public and philanthropic hospitals in the city of Fortaleza (in Portuguese), *Revista Baiana de Saúde Pública,* **34**, 321-32.

Luczynski M., Gomes M.D.V.N., Alves S.R., Oliveira K.L., (2018), Diagnosis of waste management service of metropolitan health emergency hospital emergency and the metropolitan region of Belém, *Journal of Specialist*, **1**, 1-13.

Maders G.R., Cunha H.F.A., (2015), Analysis of the management and management of healthcare waste of the Hospital de Emergência de Macapá, Amapá, Brazil (in Portuguese), *Engenharia Sanitária e Ambiental,* **20**, 379-388.

Mattoso V.D., Schalch V., (2001), Hospital waste management in Brazil: A case study, *Waste Management and Research*, **19**, 567-572.

Melo M.D.S., (2007), *Study on healthcare service residues at the university hospital of Brasília*, MSc Thesis, University of Brasília, Brazil.

Message L.B., (2019), Diagnosis and evaluation of healthcare waste management: a comparative study among hospitals in the city of São Carlos-SP, Brazil. 2019. 258 f, MSc Thesis, University of São Paulo, São Carlos, Brazil.

Minoglou M., Gerassimidou S., Komilis D., (2017), Healthcare waste generation worldwide and its dependence on socio-economic and environmental factors, *Sustainability*, **9**, 220.

Minoglou M., Komilis D., (2018), Describing health care waste generation rates using regression modeling and principal component analysis, *Waste Manage*ment, **78**, 811-818.

Miyazaki M.E., Une H., (2005), Infectious waste management in Japan: A revised regulation and a management process in medical institutions, *Waste Management*, **25**, 616-621.

Mmereki D., Baldwin A., Hong L., Li B., (2016), *The Management of Hazardous Waste in Developing Countries,* In: *Management of Hazardous Wastes*, Saleh H., Rahman R.A. (Eds.), Intech, Rijeka, Croatia, 39-51.

Monreal, J., (1993), *Considerations on Hospital Waste Management in Latin America, In: Considerations on Hospital Waste Management in Latin America*, OPAS, Organizacion Panamericana de la Salud.

Moreira A.M.M., Günther W.M.R., (2013), Assessment of medical waste management at a primary health-care center in São Paulo, Brazil, *Waste Management*, **33**, 162-167.

Moreira I.G., Yamane L.H., Siman R.R., (2015), Qualitative-quantitative analysis of residues generated in infirmary of Santa Casa de Misericórdia Hospital of Vitória, Espírito Santo (in Portuguese), *Revista de Ciências Ambientais,* **9**, 23-35.

Nagashima A.L., de Barros J.C., Rodrigues F.C.E., (2007), Analysis of the production and solid waste generation rate of health services of the Regional University Hospital of Maringá, *Acta Scientiarum. Technology*, **29**, 131-139.

Naime R., Ramalho A.H.P.E., Naime I.S., (2006), Diagnosis of the solid waste management system of the hospital of clinics of Porto Alegre, *Uniciencias,* **10**, 103-143.

Oliveira C.R.D.R., Pandolfo A., Martins M.S., Gomes A.P., Dal Moro L., (2013), Healthcare waste management: evaluation of the procedures adopted at the hospital of the city of Guaporé-RS, *Holos*, **2**, 251-260.

Oliveira E.C., (2010), Analysis of solid waste management of health services: the case of a medium-sized hospital in the state of Sao Paulo (in Portuguese), *Periódico Eletrônico Fórum Ambiental da Alta Paulista,* **6**, 782-799.

Oliveira L.T.D., (2017), *Analysis of the waste generated by a large health institution of the mining triangle*, MSc Thesis, Federal University of Uberlândia, Uberlândia, Brazil.

Oliveira P.S., (2006), *Characterization of the waste from health services of a hospital of size III in the municipality of São José dos Campos and analysis of the execution of the management plan*, MSc Thesis, University of Taubaté, Brazil.

Onursal B., (2003), Health care waste management in India, On line at: http://documents.worldbank.org/curated/en/622811468139501507/pdf/325050PAPER0IN1r0official0use0only1.pdf.

Patwary M.A., O'Hare W.T., Street G., Elahi K.M., Hossain S.S., Sarker M.H., (2009), Quantitative assessment of medical waste generation in the capital city of Bangladesh, *Waste Management*, **29**, 2392-2397.

Pereira J.A.R., Condurú M.T., de Souza, R.M., Barros, A.J.A., (2018), Assessment of the Solid Waste Generation of Services Health Care in Hospital de Belém/Pará, In 13 Seminário Nacional de Resíduos Sólidos (in Portuguese), Brasília, Brazil.

Pinheiro L.A., da Silva E.R., (2016), Studies on solid waste from health services and environmental education (in Portuguese), *Revista Internacional de* Ciências, **6**, 21-28.

Pruss A., Giroult E., Rushbrook P., (1999), *Safe Management of Wastes from Health Care Activities*, vol. 9, WHO, World Health Organization, Geneva.

Pugliesi E., (2010), *Study of the evolution of the composition of healthcare waste and of the procedures adopted for its integrated management, in the Santa Casa de Misericórdia Irmandade Hospital of São Carlos-SP,* PhD Thesis, University of São Paulo, São Paulo, Brazil.

Ramírez L.C., González A.E., Tizze N.R., (2017), Determination and evaluation of the rate of solid wastes generation in health care centers in Montevideo, Uruguay, *International Journal of Clinical Medicine*, **8**, 652-667.

Rosa F.R., Machado Ê.L., Moraes J.A.R., (2016), Management and quantification of healthcare waste: a case study (in Portuguese), *Tecno-Lógica,* **20**, 111-117.

Rosa F.R.D., (2016), *Diagnosis of waste management in a hospital in the Rio Pardo Valley,* MSc Thesis, University of Santa Cruz do Sul, Santa Cruz do Sul, Brazil.

Saad S.A.G., (2013), Management of hospitals solid waste in Khartoum State, *Environment Monitoring and Assessment*, **85**, 8567-8582.

Salkin I.F., (2001), *Review of Health Impacts from Microbiological Hazards in Health-Care Wastes*. WHO, Department of Blood Safety and Clinical Technology and Department of Protection of the Human Environment World Health Organization, Geneva.

Santos E.D.S., Gonçalves K.M.D.S., Mol M.P.G., (2019), Healthcare waste management in a Brazilian university public hospital, *Waste Management & Research*, **37**, 278-286.

Schneider V., (2004), *Health care waste management systems: contribution to the study of variables that interfere in the process of implementation, monitoring and resulting costs*, MSc Thesis, Federal University of Rio Grande Do Sul. Porto Alegre, Brazil.

Schneider V.E., Rêgo R.D.C.E.D., Caldart V., Orlandin S.M., (2001), *Health Services Solid Waste Management Manual,* CLR Balieiro, São Paulo, Brasil.

Schneider V.E., Stedile N.L.R., Manfredini K.L., Paiz J.C., Giacomassa S.D., (2019), *Evaluation of the Contents of Waste Generation of Health Care in a Hospital School* (in Portuguese), XXXI Congresso Centro-Americano de Engenharia Sanitária e Ambiental. Panamá.

Shanmugasundaram J., Soulalay V., Chettiyappan V., (2012), Geographic information system-based healthcare waste management planning for treatment site location and optimal transportation routeing, *Waste Management and Research*, **30**, 587-595.

Silva D.F., Von Sperling E., Barros R.T.V., (2014), Evaluation of health services waste management in municipalities in the metropolitan region of Belo Horizonte (Brazil) (in Portuguese), *Engenharia Sanitária e Ambiental,* **19**, 251-262.

Silva M.S.D., Souza P.M.D., Olinda R.A.D., Santos D.A.S., Oliveira R.X.D., (2015), Knowledge of the professionals about waste management of a Midwestern hospital (in Portuguese), *Revista Meio Ambiente e Sustentabilidade,* **9**, 262-281.

Sisinno C.L.S., Moreira J.C., (2005), Eco-efficiency: an instrument for reducing the generation of waste and wastes in health facilities (in Portuguese), *Cadernos de Saúde Pública,* **21**, 1893-1900.

Spindola S.R., Moura J.M.B.M., (2017), Production and composition of health service waste in hospitals in the Vale of Itajaí (in Portuguese), *Revista de Estudos Ambientais,* **18**, 16-24.

Stankovic A., Dragana N., Maja N., (2008), Report: Treatment of medical waste in Nišava and Toplica districts, Serbia, *Waste Management and Research,* **26**, 309-313.

Taghipour H., Mosaferi M., (2009), The challenge of medical waste management: a case study in northwest Iran-Tabriz, *Waste Management and Research*, **27**, 328-335.

Teixeira M.V., Echevarría-Guanilo M.E., Knuth F.G., Ceolin T., (2018), Assessment of the waste management in basic health units from a South Brazilian city (in Portuguese), *Revista de Pesquisa: Cuidado é Fundamental Online,* **10**, 824-831.

Tivirolli K., Tivirolli S.C., da Luz P.C., Fujino L.B.V., Shinzato M.P., Skowronski J., Hess S.C., (2012), Waste management in three public hospitals in Mato Grosso do Sul, Brazil (in Portuguese), *Revista Brasileira em Promoção da Saúde,* **23**, 213-220.

Tramontini A.C.B., (2009), *Solid waste health services: diagnosis and guidelines for hospital management,* MSc Thesis, University of Passo Fundo, Passo Fundo, Brazil.

Tudor T.L., Townend W.K., Cheeseman C.R., Edgar J.E., (2009), An overview of arising and large-scale treatment technologies for healthcare waste in the United Kingdom, *Waste Management and Research*, **27**, 374-383.

Urioste A., Zajac M.A.L., Aquino S., Ribeiro A.P., (2018), Reverse logistics of surgical explant in a philanthropic hospital: implementation of a new ecoefficient model of management hospital waste (in Portuguese), *Revista de Gestão em Sistemas de Saúde,* **7**, 257-273.

Uysal F., (2004), Medical waste management in Trachea region of Turkey: Suggested remedial action, *Waste Management and Research,* **22**, 403-440.

Vaccari M., Tudor T., Perteghella A., (2018), Costs associated with the management of waste from healthcare facilities: An analysis at national and site level, *Waste Management and Research*, **36**, 39-47.

Valadares C.M., (2009), *Health services waste management: study in hospitals of the Region of the Inconfidentes/MG,* MSc Thesis, Federal University of Ouro Preto, Brazil.

Valério M.C., Castanheira N.P., (2013), Qualitative-quantitative analysis of garbage produced in a public hospital in Paraná: economic viability through the correct segregation of recyclable materials (in Portuguese), *Revista Meio Ambiente e Sustentabilidade,* **4**, 44-65.

Vieira C.D., de Carvalho M.A.R., Cussiol N.A.D., Alvarez-Leite M.E., dos Santos S.G., da Fonseca G.R.M., de Macêdo F.L., (2009), Composition analysis of dental solid waste in Brazil, *Waste Management*, **29**, 1388-1391.

WHO, (2018), Healthcare Waste Fact Sheet, Geneva, World Health Organization Switzerland, On line at: http://www.who.int/news-room/fact-sheets/detail/health-care-waste.

WHO, (2011), Waste from health - care activities, Factsheet n 253, Geneva, World Health Organization, On line at: http://www.who.int/mediacentre/factsheets/fs253/en/.

Zhang H.J., Zhang Y.H., Wang Y., Yang Y.H., Zhang J., Wang Y.L., Wang J.L., (2013), Investigation of medical waste management in Gansu Province, China, *Waste Management and Research,* **31**, 655-659.