EVALUATION OF HEALTH CARE WASTE MANAGEMENT OF A HOSPITAL UNIT IN RIO DE JANEIRO CITY, BRAZIL

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SUMMARY: Health Care Waste (HCW) management should cover all planning steps physical resources, material resources and the training of human resources involved. The purpose of this study was to evaluate the pathway of HCW segregation in a Surgical Center belonging to a Rio de Janeiro hospital, by associating the physical composition, classification, and cost projected for some types of more conventional treatments and the pathogenic potential of these residues. In Brazil, the legislation used to manage the HCW obliges the generation source to treat some fractions of the waste before it leaves the hospital unit. These treatments are autoclaving and incineration, which are very expensive. The failure in managing the HCW was detected by analyzing the waste discarded, which different groups were put together and sent to be treated at high costs, certainly due to lack of professional knowledge about the process or lack of suitable material for packaging. The common residues (Group D) represented 66.68% of the total of 242.29 kg of waste observed in improperly segregated sampling. The projected cost of a treatment represented nearly 70 times more (the estimated value of R$ 1,900,800.00 per year) - a striking factor for the institution in controlling public spending.

1. INTRODUCTION

Health care waste management (HCW) is a problem in many countries due to the lack of infrastructure, population culture and the difficulty of public and private legal entities. In Brazil, the National Sanitary Surveillance Agency (ANVISA), the National Council for the Environment (CONAMA) and the Institute of the Environment of the Rio de Janeiro State (INEA) classify these wastes into Groups A (biological), B (chemical), C (radioactive), D (common) and E (sharp waste).

HCW are considered, by many authors, dangerous or infectious, representing a greater potential for environmental pollution and infections than any other type of waste [1-4]. However, a number of national and international research papers produced by the medical field and by environmental sectors state that there is no scientific evidence to prove that RSS is more dangerous or more contaminated than household solid waste [5]. For Hossain et al. [6], scientifically proven evidence on the density and survival of microorganisms in clinical waste and the risks to public health and workers involved in health care are rare.

In addition, as Cussiol [7] points out, not all waste classified as HCW is due to procedures applied to patients with infectious diseases, but to plastic surgeries, victims of accidents (automobile, falls, cuts etc) and diseases non-infectious, such as cardiac.

On occupational hazards, it is known that the potential of HCW to cause infections is much higher during generation and declines from this point, thus presenting higher occupational than environmental risk. The risks of contamination by the handling of HCW are high, both at the time of generation, conditioning and disposal, as well as during external collection and final disposal, particularly due to failures in the packaging and segregation of piercing materials [8]. Gomes and Esteves [9] point out that the segregation stage should be well understood by the employees who work in the cleaning sector of health care establishments, which often suffer from the bad segregation and packaging of HCW.

However, sharp and scarifying objects are also found in household solid waste, such as glass, porcelain, ceramics, cans, razors, pins, nails, needles etc, which, when poorly packed and without signaling the risks of cutting and drilling, can cause accidents in the workers of the formal collection and in the street scavengers and dumps [7]. Besides, waste presenting hospital characteristics are regularly being generated in households, and collected by the

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household collection service. This is due, in part, to policy changes in the health area and the creation of health and home health care services, becoming a basic requirement for the population [10]. Medical devices and instruments are used during the treatment of patients at home, thus producing a wide variety of materials: self-injection of diabetics and replacement of colostomy bags at home can also generate significant amounts of waste with hospital characteristics [11].

If management of these wastes is performed improperly, it will favor vector proliferation, water contamination, soil pollution and the emergence of diseases in the population and animals. Thus, segregation is essential, since it allows evaluating the heterogeneity of the conditioned waste, as well as the inadequacy of the disposal. Some authors [12-16] agreed that generators should meet regulatory requirements in order to consider treatment costs that can be maximized because of poor segregation.

In Brazil, whenever there are doubts as to the management and physical space of health facilities, the biosafety norms must be used, according to ANVISA's resolution of the Collegiate Board of Directors [17] which provides for technical regulation for planning , programming, elaboration and evaluation of physical projects of health care establishments, and the HCW Management Manual of ANVISA.

The regulators point out the responsibility of the generators for the management of their waste, including the generation, segregation, packaging, collection, storage, transport, treatment and final disposal, through the service waste management plan.

The management plan should be updated and address waste generation indicators, work accidents and the issue of continuing education. Therefore, it serves to implement actions that minimize public health and environmental impacts and increase the reliability of the process.

The destination covers reuse, recycling, composting, energy recovery, treatment and final disposal in a landfill or other destination allowed by Brazilian legislation. The most commonly used treatment technologies in Brazil are autoclaving, microwave, incineration and to a lesser extent ozone, pyrolysis and ionizing radiation [18].

Liu et al. [14] reported that a survey by the World Health Organization on HCW management in 22 countries had pointed to the variation in health services that applied inadequate methods from 18% to 64%. Some authors [1, 15] associate poor practices with complex decision methods, different hierarchical levels of criteria, lack of standardization and divergent understanding of classification by regulatory agencies and health professionals.

A systematic review of 150 papers on the governance structure of HCW from different countries [1] showed the public health risks in several cities and regions in Africa, Asia and the Middle East and around 50% of the world's population is threatened with environmental, occupational and public health risks.

According to Bujak [19], although some countries do not have national legislation, nor simple separation and treatment techniques, Europe stands out with a sustainable management of health care waste.

The objective of this study was to evaluate the HCW management of the surgical center of a hospital unit located in the city of Rio de Janeiro considering the aspects of segregation and physical composition of HCW and its alternative forms of destination, the projection of treatment costs, characterization of bacteria present, as well as its resistance to antimicrobial agents.

2. MATERIALS AND METHODS

The chosen experimental area was the surgical center of a hospital of high complexity located in the Rio de Janeiro City. The Figure 1 shows the sequence of steps of this study. Wastes from the surgical center were collected from the purge area weekly, during the months of March to May 2016. The samples were collected and transported to the Research Center laboratories in the Municipal Company of Urban Cleaning of the Rio de Janeiro City (COMLURB).

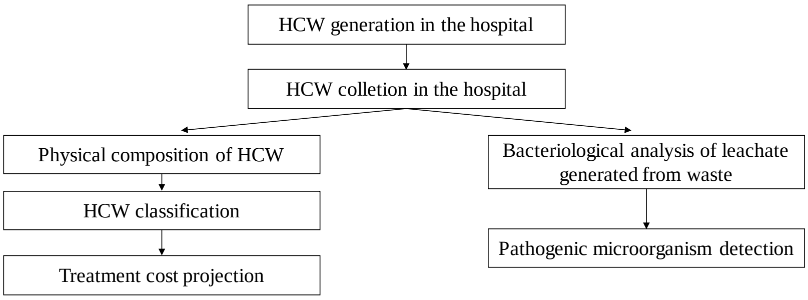

Figure 1. Schematic of the HCW post-generation stages of the surgical center.

2.1 Analysis of the Physical Composition of Health Care Waste

The separation was done by COMLURB's quarrying technique for composition and subsequent weighing in an analytical balance. The components identified in the HCW samples were classified by rubber, organic matter, textile material, metal, paper/cardboard, plastic and glass.

2.2 Detection of Pathogenic Microorganisms from Hospital Environment

After the weighing, the samples were submitted to AFNOR methodology X-31-210/92 from France [21] to obtain the leachates from 100 g of the sample and the mixture with the nutrient broth in the ratio of 1:10, at the stirring rate of 60 cycles per minute over a period of 30 minutes.

The analyzes were performed according to the Standard Methods for the Examination of Water & Wastewater - APHA [20]. The densities of total coliforms, *Escherichia coli* and enterococci were expressed in Most Probable Numbers per 100 grams of sample (MPN/100g) and determined by the Multiple Tube Fermentation Technique. In the standard Multiple Tube Fermentation Technique, volumes from 10^{-1} to 10^{-5} mL were inoculated into sets of 5 tubes containing lauryl tryptose broth (LTB; Difco).

The antimicrobials tests used for enterobacterial, enterococcal and *Pseudomonas aeruginosa* strains were supported by the CLSI - Clinical and Laboratory Standards Institute [22-23]. The Modified Hodge Test (MHT) detects carbapenemase production in isolates of Enterobacteriaceae. Carbapenemase production is detected by the MHT when the test isolate produces the enzyme and allows growth of a carbapenem susceptible strain (*E.coli* ATCC 25922) towards a carbapenem disk. The result is a characteristic cloverleaf-like indentation.

3. RESULTS AND DISCUSSION

3.1 Analysis on the Generation and Disposal of Health Services Waste

The Table 1 shows the typical heterogeneity of the HCW from the surgical center at a municipal hospital.

Table 1. Consolidated statement on components from the surgical center (n=8)

Components	%	Average (kg)	Minimum (kg)	Maximum (kg)	Standard deviation(kg)
Rubber	11.09	3.36	1.16	5.46	1.39
Organic matter	20.79	6.29	1.00	12.28	4.17
Textile material	17.57	5.32	1.70	8.64	2.90
Metal	1.13	0.34	0	0.93	0.39
Paper/ cardboard	8.40	2.54	1.40	3.90	0.98
Plastic	36.62	11.09	3.68	15.51	4.82
Glass	4.40	1.33	0	2.94	0.81

In the present work, the largest fractions of the components were attributed to plastic (36.62%) and organic matter (20.79%). These data are compatible with the plastic components (38.07%) and organic matter (12.61%) for the HCW collected in the City of Rio de Janeiro [5].

The Table 2 presents the data of this observation, with the correlation among the physical composition, the type of materials, the classification and the forms of destination, following the actual legislation for the HCW.

Waste A1 must be treated before final disposal, according to the legislation in force. The treatment can be by physical process or other processes that reduce or eliminate the microbial load, in equipment compatible with Level

III of microbial inactivation and that de-structure its physical characteristics [24].

Waste A3 should be packed separately and identified as “anatomical piece”; then cremated, buried or treated by incineration. The Subgroup A4 wastes are packed in a milky aspect bag in the absence of body fluids in the free form, and do not undergo prior treatment before final disposal [24].

Group D as food remains, cigarette and styrofoam cartons, plastic cups and cutlery and papers (crepe type) could have been segregated for selective collection, otherwise they will be considered as tailings [24].

Table 2. Consolidated statement on HCW composition, materials, classification and destination of surgical center

Composition	Materials	Group	Destination*
Rubber	Garrote and gloves without apparent waste	Biological - A4	Landfill
Organic matter	Transfusion bag for incomplete collection	Biological - A1	Autoclave
	Human hair	Commom - D	Landfill
	Human foot	Biological - A3	Autoclaving or incineration
	Skullcap; Gasses and container with blood in non-free form	Biological - A4	Disposal in sanitary landfill
	Food remains	Commom - D	Composting
Textile material	Cotton, gauze and disposable lab coat	Commom - D	Landfill
Metal	Needle	Screwdriver - E	Autoclave
	Surgical stapler	Biological - A4	Landfill
Paper/ cardboard	Drug box and crepe paper	Commom - D	Recycling
Plastic	Plastic cup and jars and needle cap	Commom - D	Recycling
	Syringes with blood in free form	Biological - A1	Autoclave
Glass	Intravenous glass ampoule and bottle	Screwdriver - E	Autoclave and Recycling

*Other forms of destination are allowed.

The heterogeneity of wastes indicated a fail in segregation because, in addition to having a high specific mass, the wastes of the waste mixture increases as if they were all originally from Group A or E. Figure 2 represents the percentages of the groups of wastes found, being those of Group D, the most generated wastes.

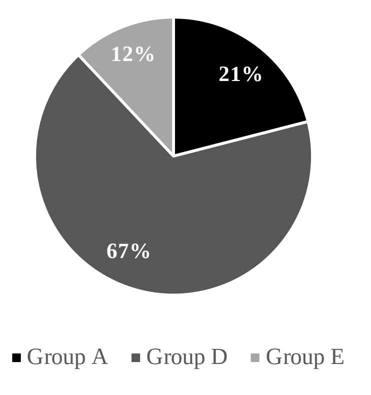

Figure 2. Percentages of HCW Groups found in the waste collected in the surgical center .

Salomão et al. [25] when evaluating the HCW segregation of a surgical center, found a percentage of 11% for biological waste and 62% for common waste consisting of paper and plastic. Maranhão et al. [26] verified the variation from 54% to 80% in a health organization of the Brazilian Navy for Group D. Rosa et al. [27], based on data from the World Health Organization [28] found 85% for Group D and 10% for Group A and E. Maders and Cunha [29] found a mixture of up to 79.6% of Group D wastes conditioned as Group A. In Casado et al. [1], it was found 68.60%. Finally, in this study, Group D prevailed in 66.68% of the total of 242.29 kg of observed wastes.

Table 3 presents an estimated cost estimate for the treatment of HCW generated in the city of Rio de Janeiro, based on the percentages found in this study for Group D.

Table 3. Projection of costs for the treatment of HCW generated in the city of Rio de Janeiro based on the percentages of Group (D) segregated as Groups A and E in the surgical center.

Projected cost considering bad segregation of Group D	Projected cost for Group D for correct segregation	Difference
R$ 5,280.00/day	R$ 75.17/day	R$ 5,204.83/day
R$ 158,400.00/month	R$ 2,255.10/month	R$ 156,144.90/ month
R$ 1,900,800.00/year	R$ 27,061.20/year	R$ 1,873,738.80/year

Obs. R$ = Brazilian currency (Real). 1 US$ = R$ 3.41 (April 17th, 2018)

From the generation data of the Stericycle Brasil Company [30], that is responsible for the HCW treatment, the average waste generated in the Rio de Janeiro City corresponded to 1.98 t/day. Overlapping the percentage of 66.68%, the value was 1.32 t per day for Group D in a given month in 2016.

In 2015, in Rio de Janeiro, the costs of autoclaving for Group A and E waste were around R$ 4,000.00 per ton and the final cost of disposal of the RSD was around R$ 56.95 per ton [31]. As such wastes are similar to those of Group D, in terms of hazardousness and physical composition, the same cost of disposal for landfill was adopted.

Since all wastes disposed of in Group A and E waste are treated as such, a roughly seventy-fold increase was assumed due to the values of the autoclaving treatment and the direct disposal in the landfill. This requires increased attention to the institution in the control of public expenditures, especially with the estimated value of R$ 1,900,800.00 per year, regarding the incorrect realization of a management stage, the value of which could be applied to a public good or service.

The results of this study were similar to those observed by other authors [1, 12-13, 16, 32] indicated that training and continuing education of health professionals were effective and efficient in the HCW management process with cost reduction. In addition, the adoption of good management practices represents the strategic tool to integrate this process into the institutional center [1].

The elaboration and implementation of the HCW management plan, using the situational strategic planning, reduced its generation and the inadequacies in the studied hospital units, through the participation of professionals and users of this unit [33].

3.2 Detection of Pathogenic Microbes from Hospital Environment

The lack of data in the literature on the microbial analysis of health wastes led to a comparison of the results of this work with those from household wastes. Table 4 consolidates data on the microbial populations found in the wastes.

Table 4. Consolidated sample of total coliform populations, *Escherichia coli* and enterococci detected (n=7).

Parameter (MLN/100g)	Average	Minimum	Maximum
Total coliforms	9.68×10^4	8×10^2	1.6×10^5
Escherichia coli	3.21×10^4	0	1.6×10^5
Enterococcus	2.32×10^4	0	1.6×10^5

There was a low incidence of total coliform populations (between 8×10^2 and 1.6×10^5 MPN/100g) and enterococci (between 0 and 1.6×10^5MPN/100g) in the samples evaluated when compared to the numbers close to 10^{10} MPN/100mL in the solid waste leachate from the bacteriological characterization work of the Municipality of

Rio de Janeiro conducted by COMLURB [34].

The microbial analyzes of the leachate obtained from the Gramacho landfill in Duque de Caxias (Rio de Janeiro State) presented values of 1.6×10^5MPN/100mL for total coliforms, and 4.9×10^3 MPN/100mL for *E. coli* in 2011. In the Seropédica landfill (Rio de Janeiro State), the average values for total coliforms in the leachate were 5×10^2 MPN/100mL [5].

Figure 3 illustrates the percentage of bacterial strains isolated in the analyzes, with strains of *Klebsiella pneumoniae* being more frequent than the others.

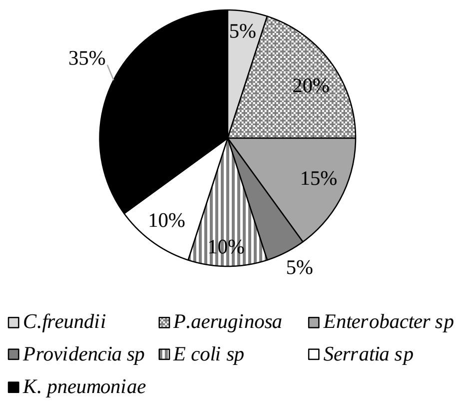

Figure 3. Percentages of bacterial strains isolated in the analysis of the waste from the surgical center.

74 HCW samples was analyzed [35] of which 93% presented contamination by *Citrobacter freündii* (3%), *Enterobacter aerogenes* (4%), *Escherichia coli* (22%), *Staphylococcus sp* (15%), *Providencia stuartii* (7%), *Serratia liquefaciens* (3%), *Salmonella enterica* (1%), among other bacteria. Table 5 shows the percentage of antimicrobial susceptibility phenotypes.

Table 5. Percentage of phenotypes identified for enterobacteria and *P. aeruginosa* for tested antimicrobials.

Bacterial group	MRA (%)	R1(%)	R2(%)	S(%)
Enterobacteria	43.41	-	-	56.59
P. aeruginosa	33.35	2.77	55.55	58.33

MRA - multiresistance; R1 - resistant to a single antimicrobial; R2 - resistance to two antimicrobials; S - sensitive.

Although *Enterobacter sp, Enterococcus sp, Escherichia coli, Klebsiella pneumoniae, Providencia sp, and Serratia sp* strains confirmed the presence of fecal matter in the wastes, only *E. coli*, *Enterobacter sp* and *K. pneumoniae* presented a profile as producers of extended spectrum beta-lactamase enzyme, however no carbapenemase-producing strain was detected.

Cussiol [7] has already pointed out that the potential of HCW to cause infections is greater during generation with subsequent decline afterwards, presenting more occupational risks than environmental, certainly due to punctures and cutting wastes.

4. CONCLUSION

This research allowed the following conclusions:

- HCW belonging to Group D corresponded to 66.68% of the total 242.29 kg of waste segregated as Group A and E, resulting in an estimated cost of 70 times higher than the regular cost.
- The presence of cotton, paper, plastics and human parts, mixed in the same container, highlighted the failure in the handling, certainly for lack of knowledge on the part of the professionals;
- Wastes identified as belonging to Group D were verified as potential materials such as food waste and plastic cups for composting and recycling, following the goal of circular economy;
- The HCW found in the sampling may present a potential pathogenic risk to patients and the population,

especially to those with impaired immune status;

- Strains of *Citrobacter freündii, Enterobacter sp, Enterococcus sp, Escherichia coli, Klebsiella pneumoniae, Providencia sp, Pseudomonas aeruginosa, Serratia sp* were identified, and the strains of *K. pneumoniae* prevailed in all samples (30.43%);
- There were bacterial strains with multiresistant profiles, but none of them were carbapenemase producing;
- The presence of enterobacteria and *Enterococcus sp* confirmed the presence of fecal matter in HCW. This points to the need to use protective equipment and hand hygiene before and after procedures to prevent the spread of these microorganisms;
- The diagnosis of HCW segregation pointed to mistakes observed by the mixture of different groups of waste packed in plastic bags designated for Group A waste and cardboard boxes designated for Group E;
- As long as the managers of the health facilities do not manage the HCW appropriately, by means of monitoring and training professionals, unprepared people will have autonomy to decide in which package the waste generated in health care facilities must be disposed;
- Under the conditions studied, there was an impact on the public budget arising from HCW management failure - strategic situational planning should be a tool applied by the manager to involve the entire institution in the control of public expenditures.

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