HEALTHCARE WASTE INDICATORS FOR ASSESSING THE INFECTIOUS WASTE MANAGEMENT IN THE PUBLIC HOSPITALS OF LA PAZ (BOLIVIA)

Navarro Ferronato[1,*], Marco Ragazzi[2,] Marcelo Antonio Gorritty Portillo[3], Edith Gabriela Guisbert Lizarazu[4], Vincenzo Torretta[1]

[1] University of Insubria, Department of Theoretical and Applied Sciences, Via G.B. Vico 46, I-21100, Varese Italy
[2] University of Trento, Department of Civil, Environmental and Mechanical Engineering, via Mesiano, 77, I-38123, Trento, Italy
[3] Universidad Mayor de San Andrés (UMSA), IIDEPROQ, Calle 30, Cota Cota, La Paz, Bolivia
[4] Universidad Mayor de San Andrés (UMSA), Department of Environmental Engineering, Av. Mariscal Santa Cruz 1175, La Paz, Bolivia

*Presenting author email: nferronato@uninsubria.it (N. Ferronato)

Abstract:

Healthcare waste management in the developing word is a human health and environmental burden which should be solved for improving sustainability. Therefore, solutions should be introduced in short terms, concerning management, planning, financial supporting and know-how. The paper introduces the application of an integrated indicator for assessing the main weak points regarding healthcare waste management in cities, for evaluating the healthcare waste management system. The objective is to suggest a new management tool for improving planning in hospital and cities as regard collection, transportation, treatment and final disposal of healthcare waste. The method was introduced in Bolivia, in a developing big city where healthcare waste represent an issue mainly as regard final disposal and the diffusion of infectious pathologies. Results suggested that, in Bolivia, the application of such indicator could be useful for considering which solution could be applied for improving local management, in a simple and integrated manner. Basically, the tool was applied for introducing a preliminary study for the application of future plans, especially concerning healthcare waste treatment. The method could be applied in other context worldwide, with a focus on the developing world. Moreover, the approach is of interest for improving sustainability, human health and circular economy. Analysis of the context is introduced, as well as details of the method applied.

Keywords: Developing countries, healthcare waste management, hazardous waste, sustainable development, waste management indicators

1. Introduction

Healthcare waste management (HWM) in developing countries represents a health and environmental concern due to its mismanagement and lack of treatment [1, 2]. The absence of no effective activities for healthcare waste (HW) minimization, separation, and recycling [3], and the low levels of training and consciousness of waste legislation [4], improve the diffusion of diseases, decreasing the quality of the service provided and the security of the operators [5].

Key issues which affect the generation rates of HW are the number of bed in hospitals [6], the amounts of occupied beds [7], and the income of the country [8]. Moreover, the increase in using of disposable medical products, also due to improved medical care, and the growth of the world population, contributes to the increase of HW generation [9], enhancing difficulties in waste management. Therefore, the mean years of schooling, life expectancy, and the CO_2 emissions could be used as statistical predictors since positively affect the HCW generation [10]. In a developing country, the range of HW generation could vary from 0.02 to 3.2 kg/bed-day,

since there is a huge difference among healthcare facilities (Diaz et al., 2008). Therefore, in low-income countries, the lack of programs for waste minimization, appropriate treatment and trained personnel [11] affect the HWM planning and future improvements [12].

These considerations are also effective in Bolivia, low-middle income country where management activities about solid waste are still under development. This study introduces the HWM activities of Bolivia, with La Paz as case study, for the application of an integrated tool for assessing current HW. La Paz is a developing big city introduced in a singular geographical area of the Andean plateau, where solid waste management (SWM) is still in progress [13]. The analysis of the HWM of public hospitals is introduced within the paper, focusing on collection, storage, treatment, monitoring and staff awareness [14, 15].

For evaluating the state of HWM, an indicator set was applied and developed in this research, according to the management directives presented by the World Health Organization (WHO) in 2014 [16]. The indicator set is applied as consequence of the requirement of a simple and effective methodology for evaluating HWM issue of La Paz. Other authors suggested that there is the need for a holistic approach and information platform to the decision-making process in HWM [17], for improving a city scaled capacity building and public's awareness [18]. Generally, there are three key areas of analysis: budget support, developing policies and legislation, technology and knowledge administration [19]. Such arguments were added within the indicator developed within the research, as well as collection and transportation methodologies, treatment and final disposal.

The aim of the paper is introducing and suggesting a management tool useful for improving HWM in Bolivia, as case study for Latin America developing countries. The current SWM is reported, as well as the method used for the analysis. Basically, the integrated indicator was developed for assessing the main weak points of HWM, with considerations about data used. The final and main objective is evaluating main pros and cons of the system for introducing an appropriate treatment plant. Results are introduced concerning data available: the situation of hospitals in 2003 is described thanks to data obtained by the review of local documents while HWM in the city is introduced in function of a field work conducted in 2018.

2. Methods

The research could be divided in three main parts:

- development of the indicator,
- the review of local documents about HWM,
- the field studies conducted within the city.

The study was applied to assess the current HWM for introducing a treatment plant. For this reason, local and current reliable data are required, while an impartial and integrated methodology was also necessary. Therefore, local universities, international non-governmental-organizations (NGOs) and the private sector were involved, in order to build a multi-stakeholder and multi-disciplinary research. The field work and the cooperation with the local partners was of utmost importance for fulfilling the indicator. In particular, the methodology adopted was the interview to local engineers and operators and the field inspection of the areas. To date, the field inspection has been applied only within the sanitary landfill and the external area of the hospitals, while data about HW production and management available in local documents were reviewed.

2.1. The indicators

The indicator set was built for this study for summing up the management activities applied in La Paz. The structure of an indicator set introduced by Wilson et al. [20], for the assessment of municipal solid waste in developing countries, was used and adapted with the specific analysis of HW. The HW indicator is composed of 5 sub-indicators:

A. collection and selective collection,
B. storage,
C. local treatment,
D. maintenance and monitoring,
E. awareness, security and prevention.

Each indicator set is divided in 5-7 criteria, which could receive a note from 0 to 20, with scale of 5, in function of the indications provided. Finally, the indicator is presented in percentage, from 0 to 100%, by a radar scheme. The percentages are summed up in a traffic-light scale, in agreement with data in table 1. This approach allows providing a simple indication of the current situation for each indicator in a simple way.

Table 1: Evaluation scale for the indicator set

Percentage obtained	System analysis

0-19%	Unsustainable
20-49%	Problematic
50-69%	Satisfying
70-89%	Fine
90-100%	Excellent

Moreover, the average result of the indicators, introduced for summing up the current HWM of public hospitals, is presented in parallel with a final indicator set concerning the public management applied in the city (Indicator F). Such municipal indicator, which represent the sixth indicator, is built for assessing HWM at municipal level. Therefore, the city could be presented with only one scheme, which provided the main characteristics of the city about HWM. The indicators, for each hospital, should be presented with the relative information about its characteristics:

- Number of beds
- Percentage of beds occupied per year
- Number of patients per year
- Level of the hospital
- Number of workers
- Number of solid waste produced per year (for each type)

2.1.1. The criteria

Each indicator is divided in different criteria, which are divided in other 5 sub-criteria. Each sub-criterion is useful for providing the final score to the indicator, in function of its description and of the data obtained. Basically, each sub-criterion have an explanation which provides indication of an average situation which could be detected in a hospital. The lower score, or the first sub-criterion, describes the worst condition detectable, while the highest score, or the last criterion, contains the best situation. In function of the argument, the criteria introduced could be evaluated by interviewed to local stakeholders, director, staff and operators, or by the field inspection and visits to the sites. The criteria which forming part each indicator are summed up in Table 2. Descriptions of each sub-criterion are here omitted.

Table 2: Description of the indicators set and of the criteria

Indicator code	Criterion number	Title	Description
A. Collection and selective collection	A.1	Percentage of selective collection	This criterion assess the selective collection of HW. The score is provided in function of the percentage know and demonstrated of selective collection. In particular, the higher range assumed is of 71-100% of selective collection of HW and the absence of infectious waste within the municipal solid waste.
	A.2	Intermediary storage	Here the quality of the storage system is assessed. The main topics considered are the bags used for the storage, as well as the containers, and the areas used.
	A.3	Internal transport	The criterion considered the transport of the HW through the area of generation and the first temporary storage. In particular, the assessment considers the awareness of the staff, the quality of the bags and containers used specifically for the transport, the protection equipment used by the staff and the presence of regulations.
	A.4	Times of transports to external areas	The collection time in internal areas is considered. The service should be applied daily and regulated. The highest score could be achieved by the collection every morning, evening and night, in predetermined areas.
	A.5	Use of personal protection equipment	Simply, the criterion analyze the availability of gloves, suits, goggles… every time that the HW is managed, as well ad the sterilization of the containers after transportation.
	A.6	Typologies of waste collected in separate containers	The types of HW selected is important for understanding the quality of the storage and transportation. The criterion considers the municipal solid waste, the sharp waste, infectious, radioactive, pathogens, liquids, chemical and drugs and the wastewater.
B. Storage	B.1	Awareness and consciousness of the	Quality of the collection provided is assessed in term of capacity and know-how of the operators, the specialization of the

		staff for the transporting process	companies involved in the system, the use of personal protection equipment, awareness of the personnel, and the monitoring system.
	B.2	Temporary storage area on-site	The area of the massive storage of HW in hospital is analyzed in function of its maintenance, cleanness, typology and allocation, as well as the staff who could enter the area.
	B.3	Storage time before treatment or external transport	The time required for transporting the HW from on-site massive temporary storage to the final disposal or treatment should note overcome the 24h. The maximum score could be obtained if the HW is transported every 12h, in order to minimize the risk of spread of disease.
	B.4	Personal protection equipment of the staff	Differently between criterion A.5, this criterion assess the use of personal protection equipment used by the staff whit transport the HW from the hospital to the final disposal or treatment plant.
	B.5	Container used for the temporal storage of HW	Differently between criterion A.2, the criterion analyzed the quality of the containers for the massive storage inside or outside the hospital. In particular, the area considered is the second temporary storage present in the healthcare facilities examined.
C. Local treatment	C.1	Treatment of the infectious and sharp HW	The criterion simply assess the presence of a treatment plant for the sterilization of the HW. Basically, the quality of the treatment is considered for each waste typology, in order to evaluate the availability of the treatment both at large scale or small scale (laboratories or the internal area of clinics).
	C.2	Precautions applied during the treatment	The criterion considered the precautions used before treatment in an integrated manner, such as the monitoring of the emissions, the quality of the containers used, the trituration before treatment, or generally the pre-treatment, the operation and maintenance of the plant.
	C.3	Wastewater treatment applied within the hospital	Wastewater treatment is considered for closing the loop of the HW treatment. In particular, the treatment of body fluids, chemical, the use of the sewage system and the treatment of the sludge.
	C.4	Percentage of HW treated on site	In agreement with the criterion A.1, the criterion analyzed the quantity of waste separated treated on-site. Specifically, the percentage of waste treated is assessed, in function of all the HW produced.
	C.5	Treatment area	The quality of the area used for the treatment is considered, in function of quality of the cleanness, the monitoring and the quality of the structure used (roof, barriers…)
D. Maintenance and monitoring	D.1	Responsible staff for system monitoring	For the monitoring and management of the system is required a manager, with the implementations of annual reports. This criterion assess the accomplishment of such manager and its application.
	D.2	Periodic assessment of the solid waste produced	Monitoring of the selective collection system by the analysis of the quantities produced and material analysis. The analysis should be applied diary in terms of quantities produced, while monthly a report should be drafted.
	D.3	Monitoring of the storage areas and cleaning	The criterion is in agreement with criterion D.1. The quality of the monitoring system should be coordinated by a manager and by entrained staff. The maintenance of the area is effective, and the cleaning/sterilization is applied daily: such indications are coordinated and monitored.
	D.4	Assessment of service quality	The assessment considered mainly the opinion of the users of the hospital for analyzing the public opinion. The opinion of the users is considered for improving the cleaning applied, while yearly a report about the topic is drafted.
	D.5	Assessment of expenses and economic sustainability	The financial sustainability should be analyzed in order to improve the system. For that purpose, the expenses should be carefully monitored, data should be reliable and constantly collected, the administration should be focused on it. Finally, the criterion analyzed the financial sustainability.
	D.6	Control and monitoring of the injuries of the staff	This criterion is introduced for assessing the monitoring system about the illnesses of the staff and the correlation between disease and sterilization. In particular, it is focused on the monitoring systems.
	D.7	Cooperation with external units for	Cooperating with private companies for the monitoring and maintenance system allow improving the quality of the

		assessing the system	healthcare facility. Such external company could be applied for the cleaning and the collection systems, as well as monitoring of the collection and planning.
E. Awareness, security and prevention.	E.1	Internal rule	Internal regulation are assessed in function of its reliability and application. The organization of training and seminars could improve the system and such activities are evaluated within the criterion.
	E.2	Information campaigns and activities for the staff	Correlated with criterion E.1, this criterion considers the application and organization of seminars, reunions, for the staff, among other training activities. The main objective is to assess the quality of the information provided and the time used during the year for these activities.
	E.3	Diffusion of informative material about hygiene and good practices for HWM	In agreement with the indicator D, this criterion considered the quality of the information provided to the users for accomplishing with the rules of hygiene. The same should be introduced for the staff, in order to constantly inform about such good practices. The criterion follows the indication of the criterion E.2, although qualify only the use of diffusion material.
	E.4	Vaccines to local staff	Staff should be controlled and vaccinated for reducing the risk of illnesses. These activities should be obligatory, with an appropriate monitoring system.
	E.5	Regulations and methods for preventing injuries	In agreement with criteria D.1, D.5 and B.5, this criterion assess all the activities applied for the prevention. Here the application of rules, the use of good infrastructures and information systems is assessed in an integrated manner.
F. HWM at city level	I.	Methodologies of centralized treatment and final disposal	The criterion assess the method of final disposal or the treatment applied. In particular, it introduces the engineering of the final disposal, the environmental monitoring and the monitoring of the solid waste introduced.
	II.	Quality of the transport from hospitals to the treatment plant or final disposal	Here, the quality of the transportation is assessed, in terms of use of personal protection equipment, safety precautions, separation of the waste for each topology, sterilization of the containers, and use of appropriate bags.
	III.	Local and national Laws	The criterion considered the application and the presence of reliable regulation and Laws about HWM. The law should speak about final collection, treatment and final disposal, analysis of the risk and monitoring, cost of the solid waste and sustainability.
	IV.	System monitoring	The analysis is conducted for evaluating the method of the monitoring applied within the study area. In particular, the presence of a specific public body which could qualify the characteristics of the HWM system.
	V.	Financial sustainability and investing	The percentage of economic resources that covers the expenses is considered within this criterion. Furthermore, the analysis of the investment is carried out, with a particular focus on the cost covered by the income due to HW inflow into the final disposal site.
	VI.	Collection time	The criterion analyzed the daily timescale for the provision of the HW, as well as the rule for its application. Moreover, the criterion assess the quality of the monitoring and specifically the method for the application of the selective collection.
	VII.	Personal protection equipment	The quality of the personal protection equipment is assessed, as well as the monitoring of its use and the awareness of the staff involved in the treatment or final disposal system.

2.2. Literature review

First data were available from a study introduced by the non-governmental organization (NGO) Swisscontact in 2003 [21], from the local Government and the private sector working in the field of healthcare waste management. In particular, only public hospitals were considered. Data available in this document refers to a project of selective collection applied in whole Bolivia, so quality of the data obtained could not be assessed. However, the main information available regards:

- Solid waste quantities produced,
- Analysis of the management systems,

- Quality of the selective collection,
- Number of beds and dimension of the hospital in terms of patients attempted.

Current data about HWM in hospital are not still available due to the political and administrative issues. Although such information could be considered old and unreliable, it allows developing the indicator with real data, which could be also compared with current data, when available.

2.3. Field work

A field inspection was applied at the sanitary landfill for assessing current HW final disposal. Meanwhile, interviewes were introduced to the main experts on HWM of the local municipal government, the private sector responsible of the final disposal and the international NGOs. Such information were used for fulfilling the last indicator, about municipal HWM. The field inspection and the interviews to the local stakeholders were applied from December 2017 to April 2018.

3. Results

3.1. Field inspection and the literature review

Public hospitals in La Paz, in 2003, had a production of HW ranging from 20 kg to 300 kg per day and a number of bed from 22 to about 360. In-site treatment was not applied although a good selective collection (SC) system was implemented. Totally, the waste generated by the hospitals was about 1 ton per day, comprehensive of infectious and sharps [21].

To date, the HW is totally collected by a private sector and sent to the sanitary landfill in separate cells. After 15 years, the quantity is overall enhanced, with an amount of about 2-2.5 t per day. The cost of the management is totally in charge of the municipality, without the involvement of the hospitals for the payment of the transportation and final disposal. However, the selective collection is effective, and the hazardous wastes are separated by the municipal solid waste produced within the hospitals. The HW is collected every day and in appropriate red bags, dedicated to this kind of collection, although it is stored in inappropriate containers.

3.2. The indicators applied

The introduction of the indicator set allows comparing the hospitals. However, the indicator set should be introduced in other contexts in order to understand the applicability of the method. At municipal level, collection and sorting received a good score, while financial sustainability, final disposal and personal protection could not be considered satisfying. The main results are reported in Table 3.

Table 3: Results of the HWM indicator applied for the city (indicator F)

	Criteria	Score obtained
I.	Methodologies of centralized treatment and final disposal	10
II.	Quality of the transport from hospitals to the treatment plant or final disposal	15
III.	Local and national Laws	15
IV.	System monitoring	15
V.	Financial sustainability and investing	5
VI.	Collection time	15
VII.	Personal protection equipment	10
	Satisfying	61%

The comprehension of the current HWM is of utmost importance in order to select the best HW treatment option which should be applied. For this reason, an average indication of the quality of the hospitals in 2003 is reported in order to have an example of the past situation about HWM. In Figure 1 are reported the results obtained, schematically depicted in a radar diagram. Though the current situation of HWM should be considered for the application of the indicator, the results provided an example of the application of the results obtainable.

Results suggest that the main issues regarding HWM are the awareness, monitoring and treatment. This is due to the lack of organization and awareness on the importance to apply new plans and project for reducing environmental and health issues. Such three indicators obtained a score below the 35%, which allows consider the system as problematic. The worst consideration could be introduced as regard the treatment. Essentially, the considerations available in 2003, could be reported also for the year 2018, since the application of any kind of

treatment system is still lacking. For this reason, rise the need to apply new management projects about this theme, in order to improve local sustainability, also in agreement with the sustainable development goals (Objective 12).

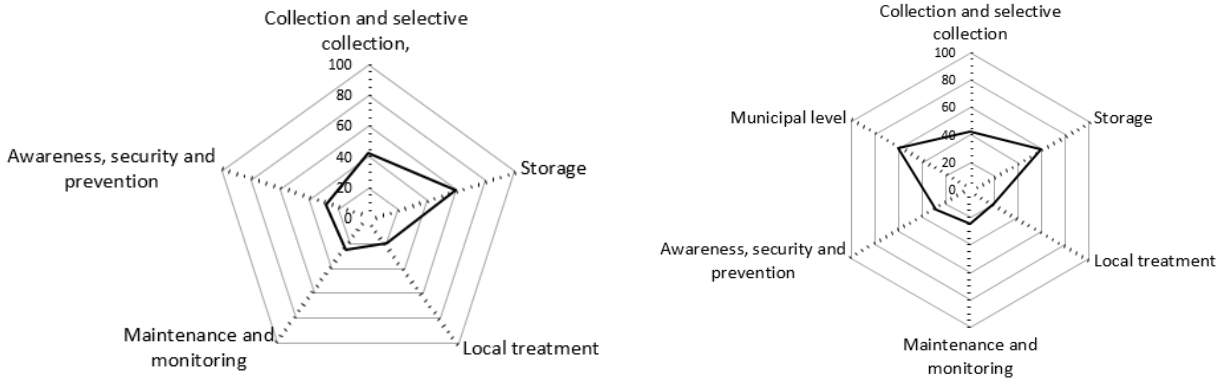

Fig. 1:Example of the results obtained for (a) a public hospital and (b) the average results obtained for the hospitals analyzed with the introduction of the indicator F.

4. Discussion

An effective planning of HWM is difficult in developing countries, often for the lack of proper tools and methodologies [22], among other factors. Basically, the main objective which should be achieved by such low-income countries is the proper separation of infectious and municipal wastes at the source, which is an essential step towards mitigating environmental and health risks and minimizing the cost of the HWM [23]. However, the waste source separation rate suffer from insufficient application of the operating procedure, which could encourage the system efficiency as well as the reduction of the costs, also in developed countries [24]. It has been demonstrated that the selective collection of HW allows decreasing the costs for the hospitals, whereas the costs for the clinics and private healthcare centers increase: the increased cost could be justified when more clinics and centers dispose of their HW correctly [25].

The application of recycling of sterilized plastic and metal parts, mechanical needle removers, safe transport and storage, appropriate treatment, documentation, training, and equipment maintenance could improve the quality of the service, reducing environmental and health risks [26]. Many treatment plants could be considered for reducing HW impacts. Steam autoclave is the most used to sterilize bacteria in order to determine an alternative to incineration technologies [27]. However, other appropriate machineries could be considered [16].

The study presented in this paper could be considered the first step for the application of appropriate technologies, since studies of the management background are of utmost importance for assessing the best future scenario. Meanwhile, the indicator suggested could be considered a reliable tool for assessing the current HWM system in developing countries, since the availability of a list of management requirements, as well as a method for classifying the main weak points of a city or hospital, could be useful for planning future improvements.

La Paz, developing big city, could be considered a good example as regard first organization (at the source), transportation and final disposal. However, the lack of treatment plants, on-site and off-site, are the main barriers for implementing a sustainable system with the aim to reduce environmental impacts, improve the life quality of the population and progress with the management of the final disposal site.

5. Conclusions

The application and introduction of HWM indicators should be considered in order to spread the awareness of the stakeholders involved in the collection and treatment systems. Moreover, international indicators should be used for comparing globally the level of the HWM systems, with the objective to assess main weak points of each study area in function of its environmental, social and economic system.

This research could be useful as starting point for introducing this methodology, which could be assessed and applied in other contexts. The proposed indicator can be used as a decision support tool for the analysis of an efficient management of HW by government, healthcare waste management authorities and hospitals. Moreover,

this work can be considered a good contribution as regard the investigation of HWM in Latin American developing big cities, and regarding the introduction of management tools useful for understanding current management practices.

Healthcare waste management in La Paz represent an issue which should be investigated, in particular as regard appropriate treatment technologies, which represents the main problem. Regulation systems and selective selection methodologies are still in action, although the final disposal to landfill is not the best management practice which could be applied. The research applied and presented in this paper is only the first step for implementing a more complex project about the introduction of a treatment plant, in cooperation with all the stakeholders involved within the study.

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