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TOWARDS A SUSTAINABLE SUPPLY CHAIN: CONTRIBUTION TO HOSPITAL WASTE MANAGEMENT IN AN ALGERIAN HOSPITAL

The object of research is medical waste management. Healthcare activities protect health, cure patients and save lives. However, they generate waste that is harmful to public health and the environment. As a result, the management of this healthcare waste is becoming increasingly important in the field of public health and the environment. One of the most problematic places is, poor management of these issues that can put healthcare workers, medical waste workers, patients and their families, and the entire population at risk. On the other hand, poor treatment or inadequate disposal of this waste can also cause risks. From now on, the rational elimination of this pollution is one of the essential conditions for respecting hygiene rules, not only inside establishments, but also in the general environment. In this unfavorable context, we are trying through this contribution to achieve adequate management using reverse logistics practices with the main objective of resolving healthcare waste management problems while taking into account the reality of things in situ. For this purpose, an approach guided by data, carried out directly in the field, by direct contact with the different categories of health personnel interviewed, through findings, observations, audits, questionnaire and knowledge of the causes was used. This approach is based on the audit of compliance with the supply chain in the management of hospital waste in the different departments of the Constantine University Hospital (Algeria). As a result of the research it is shown that the situation is very poor given that the logistics chain is completely faulty or no step is respected. Thus, the least respected stage is storage, where no service exceeds 25 %, this is due to the fact that no clinic has an intermediate waste storage area. And the most respected is treatment stage that does not exceed 75 %. This allowed to detect the inadequacies recorded at the level of the study establishment, and even improvements are suggested for sustainable management of healthcare waste at the level of Algerian health establishments.

Keywords: *healthcare waste management, public health, priority preventive actions, reverse logistics, risk management.*

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1. Introduction

The spectacular demographic surge that most developing countries are currently experiencing, and the opening up of the economic market, is accompanied by a rapid multiplication of both public and private healthcare establishments [1]. As a result, the activities of these establishments generate considerable quantities of waste of various kinds, containing infectious, pathological, radioactive and toxic elements that are particularly hazardous to human health and the environment [2–5]. These wastes are constantly being produced in situ, and their hazards increase in proportion to the quantity produced: appropriate management of this type of waste is essential to minimize the risk to health and the environment, hence the use of reverse logistics [6–8]. Reverse logistics is concerned with the associated flows generated by direct logistics activities (waste management, packaging, returns, etc.) and with flows occurring at the customer's premises, beyond the initial supply (use and end-of-life flows). Reverse logistics refers to the flow of materials in the opposite direction up the value chain. Initially, it mainly concerned the management of waste and end-of-life products (recovery, reuse and recycling), and was part of an ecological and environmental approach [9, 10]. Reverse logistics seeks to valorize reverse flows in economic, energy or social terms. It is part of the broader issue of sustainable development, of which it is an essential link.

The hospital wastes can be plastics with potential emissions of chlorinated dioxins and furans, medical devices with mercury broken or released into the environment, sharp objects such as used syringes with their potential to contaminate and spread hepatitis and AIDS, radioactive waste produced by radionuclides used in the diagnosis and treatment of cancer with their potential risk of irradiation,

blood, chemicals, pharmaceuticals, all placentas and other human anatomical waste, corresponding to human fragments, and so on (Table 1). Poorly treated, these wastes are at the origin of certain diseases such as AIDS, hepatitis, cancer, nosocomial infections, etc. [4–14]. To better distinguish between the different categories of risk, a review of the literature on hospital risks is presented in Table 1.

Table 1

Categorization of hazardous medical waste [15–18]

No.	Types of waste	Consequences
1	– Sharp waste	– Waste that presents a danger of injury
2	– Waste presenting a contamination hazard	– Waste containing blood, secretions or excretions presenting a contamination hazard
	– Anatomical waste	– Body parts, tissues presenting a contamination hazard
	– Infectious waste	– Waste containing large quantities of materials, substances or culture media presenting a risk of spreading infectious agents (cultures of infectious agents, waste from infectious patients in isolation)
3	– Drug waste	– Medicines waste, expired medicines and containers that have contained medicines
	– Cytotoxic waste	– Expired cytotoxic, cytotoxic remnants, cytotoxic-contaminated equipment
	– Waste containing heavy metals	– Batteries, mercury waste (broken thermometers or blood pressure gauges, fluorescent or compact fluorescent bulbs)
	– Chemical waste	– Waste containing chemical substances: leftover laboratory solvents, disinfectants, development and fixing equipment
4	– Pressure vessels	– Gas canisters, aerosol cans
5	– Radioactive waste	– Waste containing radioactive substances: radionuclides used in laboratories or nuclear medicine, urine or excreta from treated patients

This waste can also be produced by people who treat themselves without the help of a healthcare professional or facility. Examples include people with diabetes, viruses (hepatitis, herpes, AIDS) or multiple sclerosis [19]. They may also be users of punctual treatments such as heparin, or drug users. Inappropriate management of this type of waste, whether in the hospital or elsewhere, exposes anyone who comes into contact with it to the risk of infection and contamination by various viruses, and increases the traumatic, toxic, radioactive and psycho-emotional risks for healthcare professionals and hospital users, in addition to the damage caused to the environment, notably through the contamination of soil, water resources and air [20, 21]. Reverse logistics works closely with environmental protection. In fact, it manages everything that has been used and is now discarded, so that the manufacturer can still do something with it.

Today, the issue of hospital waste is becoming increasingly acute. Various publications and surveys have shown that current conditions for the disposal of hospital solid waste are not always satisfactory [22–24], particularly in areas where there are too many patients exceeding hospital capacity, creating a major waste management mess. Subsequently, while the environment in general has long been recognized as a key determinant of future health, the particular environment represented by the healthcare setting is proving to be a potential purveyor of public health problems, including infectious diseases, toxic overload diseases and even cancers [5]. These wastes are of different kinds:

– soft waste, objects soiled with blood such as strips, absorbent cotton, etc.;
– solid sharps waste, whether soiled or not, such as syringes, injection pen needles, lancets, etc.

They can be the cause of accidents when disposed of with household garbage or put with packaging at the selective collection:

– for users and their close entourage (family, children, etc.);
– for staff responsible for collecting and sorting household waste;
– for all road users;
– to preserve the environment (disruption of ecosystems, depletion of the ozone layer, soil, water and air pollution, etc.).

These environmental threats represent a major risk to human health (appearance and/or recrudescence of various pathologies: cancerous diseases, infectious diseases, congenital malformations, cardiovascular and respiratory pathologies, reduced quality of life and well-being, etc.) [10, 25]. As a result, and in view of the large quantities of waste produced by healthcare establishments and the risks involved, as well as the increased interest in infection prevention, hospital waste management is becoming an increasingly important issue [26, 27].

The aim of research is to initiate reflection on health and environmental concerns, the opening of national debates on the harmful effects produced by the various health establishments, in particular hospital waste, and the importance of strict application of the envisaged regulations. It's an opportunity to inform and raise awareness among those concerned, the authorities and public opinion about the harmful effects of hospital waste on patients, employees and the environment. This will awaken the minds of those concerned and the authorities to the harmful effects of waste, so that procedures and legislative provisions can be put in place to develop safe, sustainable action plans to prevent, reduce and/or eliminate pollution, harmful effects and nuisances, or even engage in a culture of sustainable improvement and prevention.

2. Materials and Methods

The working method envisaged is based on an audit of compliance with the rules and regulations in hospital waste management in the various departments of the Constantine university hospital, with the aim of initiating reflection on environmental concerns, opening up national debates on the harmful substances produced by the various health and veterinary establishments, in particular hospital waste, and the importance of strict application of the envisaged regulations. These environmental threats represent a major risk to human health, and indeed to humanity as a whole. To assess these expectations, several approaches have been proposed in the literature, and the tools used depend mainly on the nature of the data and knowledge available to build a behavioral model of the real system, including the behavioral phenomenon.

In order to facilitate this management and enable managers to make the best possible decisions, it is possible to base this research on a data-driven approach, carried out directly in the field, through direct contact with the various categories of healthcare staff interviewed, namely: findings, observations, visits, audits, questionnaire and knowledge of the causes, Fig. 1.

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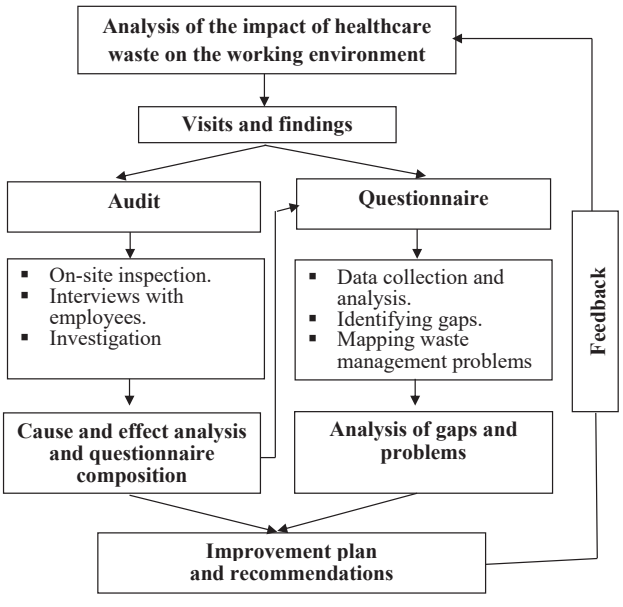

Fig. 1. Working methodology

This study was carried out at the Constantine university hospital, where 20 departments of various types (medical, surgical, laboratory, etc.) were visited. The target population was all staff involved in hospital waste management: doctors, pharmacists, paramedical staff (nurses, laboratory technicians, hygienists) and cleaning staff. The total number of respondents was 147.

The problem is presented as an audit of the various departments, followed by organized questioning, which leads to the gathering of information and analysis of the results. This method of data collection is therefore both a means of communication and a tool of knowledge [28–30]. It is a qualitative study that gathers information to understand and explain the facts of managerial techniques in hospital departments. It is a dialectical process between a theoretical problem and a research field [31, 32]. The main interest of this work began with an audit for an objective assessment of reality, followed by a questionnaire geared to the shortcomings observed, in order to choose the current modes of action. This makes it possible to gather a large amount of information, both factual and subjective, from a large number of representative individuals.

3. Results and Discussion

3.1. Observation of malfunctions. During our visit and observation period, it is possible to note the following situations, Fig. 2. These original images raise a fundamental question about hospital waste management.

In addition to these field images, let's also note the following malfunctions:

– Lack of internal management plans and/or procedures.
– Ignorance of regulations and texts in force.
– Sorting at source is not respected.
– Non-compliance with instructions.
– No reliable data on quantities produced.
– No uniforms for cleaners.
– Uncertainty about roles and responsibilities.
– No coordination between departments.
– No respect for packaging, no bag labelling.
– Bins occasionally washed due to lack of water.
– Provision of an allocation for maintenance and cleaning, but no specific budget for waste management.
– Lack of equipment.
– Containers used to collect sharp waste are often unsuitable.
– Non-conforming bags.
– No suitable vehicles.
– Location of bags near patients.
– Unavailability of storage area.
– Disturbing overflows of garbage bins.
– Discharge of wastewater from dialysis departments into the environment.
– Frequent water cuts.
– Frequent power cuts.

These dysfunctions, observed in situ, enabled to carry out an audit of the various departments to gain a better appreciation of the situation. On the basis of these findings, a survey questionnaire was then drawn up for employees to help identify the shortcomings and malfunctions in waste management.

Fig. 2. Some photos that define the waste situation at the hospital

3.2. Discussion and analysis. The detailed analysis of our audit work on hospital waste management highlighted the following particularities, Table 2. The results were obtained concerning the degree of compliance with the practices of the different stages of hospital waste management from the 18 departments, where each graph curve of the Fig. 3 represents the percentage of compliance with a single stage of hospital waste management by all clinics.

Table 2

Results on compliance with waste management practices

Service	Sorting (%)	Packaging (%)	Storage (%)	Transport (%)	Treatment (%)
Epidemiology service	100	50	25	33.33	100
Occupational medicine	42.85	50	0	33.33	100
Burn center	33.33	0	25	33.33	50
Gastroenterology	14.28	0	25	66.66	100
Orthopedics A&B	66.66	33.33	25	66.66	50
Pediatrics	71.42	50	25	33.33	100
Neurosurgery	44.44	33.33	25	33.33	50
Dermatology	57.14	50	25	66.66	100
Cardiology	33.33	33.33	25	66.66	50
Hemodialysis	71.42	50	25	33.33	0
Resuscitation	57.14	50	25	33.33	100
General surgery B	57.14	50	25	66.66	100
Laboratory of Toxicology	55.55	33.33	0	33.33	50
Laboratory of Bacteria	77.77	33.33	0	66.66	50
Laboratory of Biochemistry	33.33	33.33	25	33.33	50
Laboratory of Histology	66.66	33.33	0	33.33	50
Nuclear medicine	55.55	33.33	25	66.66	50
Internal medicine	28.57	0	25	66.66	100
Hematology	57.14	50	25	66.66	100
ENT	57.14	50	25	33.33	100

Fig. 3 represents the results of the Table 2, where it is possible to the difference in healthcare waste management at hospital level.

Observation: It is possible to see that there is a disparity in the management of healthcare waste at the level of each department, where the regulation is not respected. It can also be seen that the least respected stage is storage (black curve).

For greater clarity, Fig. 4 shows the different stages of hospital waste management for each department, also for better understanding of logistics mapping at the hospital level.

Observation: let's note that the least respected stage is storage (black curve), where no department exceeds 25 %, and this is a very low value. This is due to the fact that no clinic has an intermediate waste storage area, and waste is left either in the corridors or the washrooms (Fig. 2). Thus, there is no traceability of hospital waste to calculate the quantity generated. Next, let's note that the second least respected stage is packaging (red curve), where it does not exceed 50 %. This is due to non-compliance with the packaging rules required by the regulations, where we find, for example, poor-quality, non-resistant waste bags. Then there are the two stages, sorting and transport, which vary from one department to another, with an average close to 50 %. This variance in the sorting stage is due to non-compliance with the sorting of chemical and toxic waste (red stream) by the departments generating this type of waste. Concerning the transport stage, there are vehicles dedicated to transporting waste to the processing area, but there is a lack of carts for moving service waste to the vehicles, as a result, the agents move them manually, which explains this low value. Finally, it is possible to find that the treatment stage is the most respected, with an average of almost 75 %, thanks to the availability of the hospital's banalization method for infectious risk waste. This method is less harmful to the environment. The variance is due to non-compliance with chemical and toxic waste treatment by clinics that generate this type.

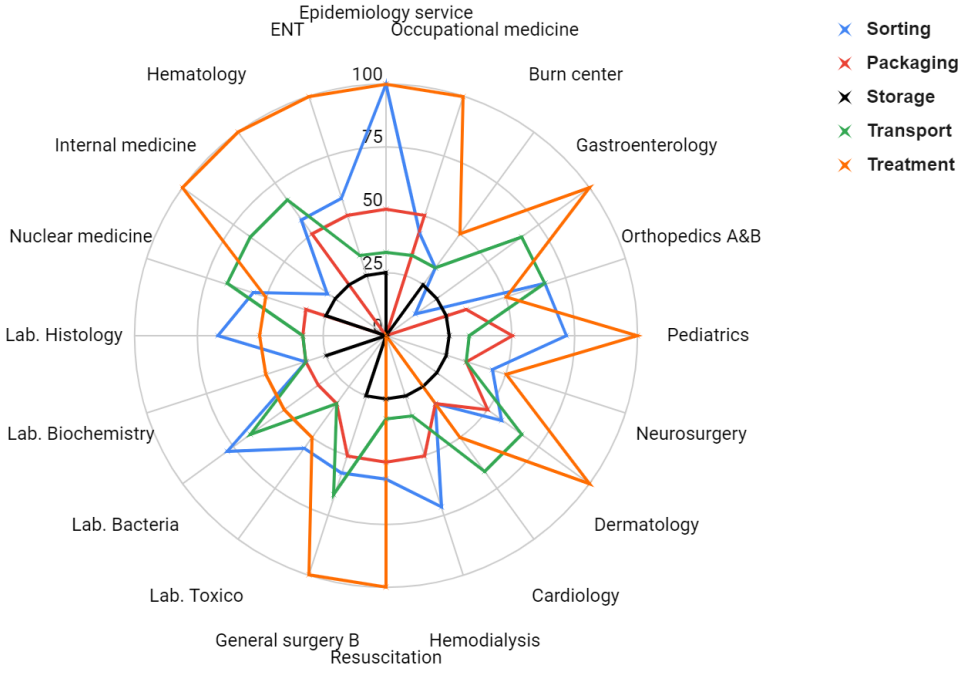

Fig. 3. Representation of the respect of each stage in the reverse logistics by services

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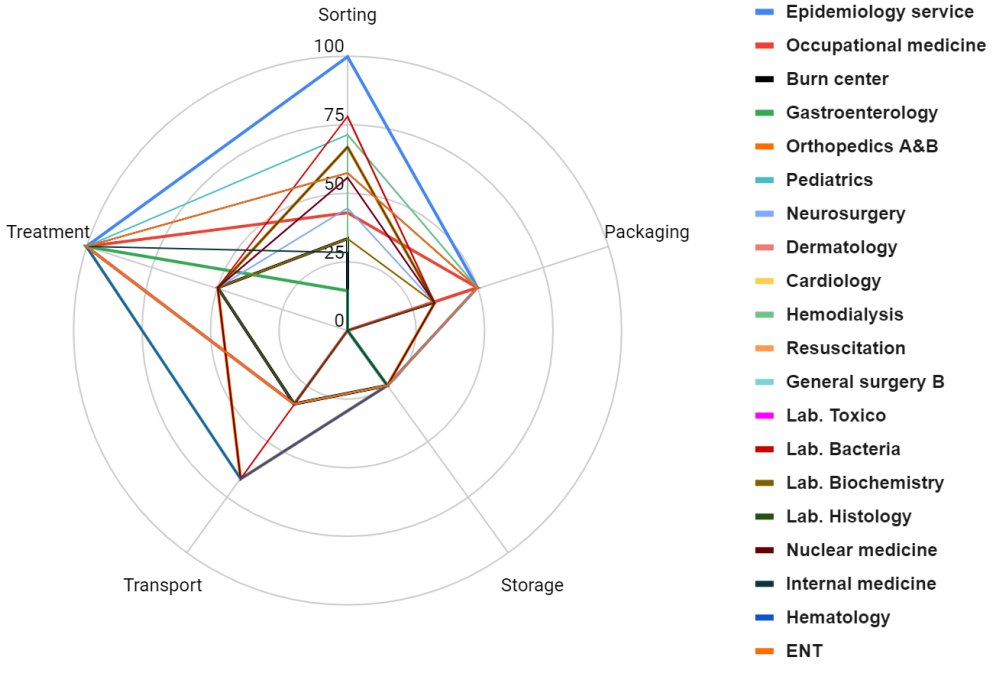

Fig. 4. Representation of compliance with the various stages of hospital waste management at the level of each department

On the basis of these audit results, a questionnaire was drawn up for healthcare staff to help them better understand the shortcomings and management problems in the hospital environment. The total number of respondents was 147, comprising 72 paramedics, 58 doctors, 9 housekeepers and 8 pharmacists. The results in Table 3 show that the majority of these respondents were women (81.6 %) and men (18.4 %), most of whom (53.7 %) were under the age of 30, with less than 5 years' experience (57.1 %). Let's also find that almost half (54 %) said they are vaccinated against hepatitis B, but most doctors are not vaccinated (63.8 %).

Respondents to this questionnaire are distributed as follows (Fig. 5).

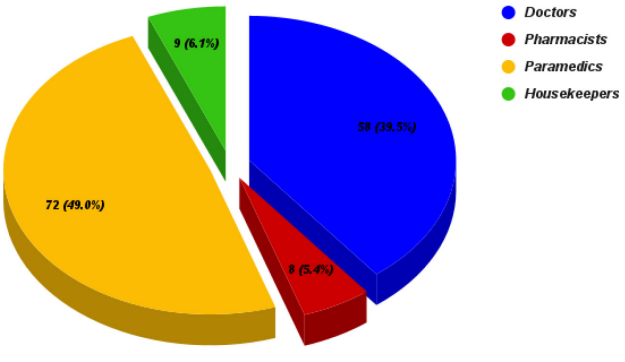

Fig. 5. Healthcare staff participated in the study

Table 3

Sociodemographic characteristics of respondents ($n = 147$)

Sociodemographic characteristics			Doctors	Pharmacists	Paramedics	Housekeepers	Total
Gender	male	frequency	13	1	13	0	27
		percentage	22.4 %	12.5 %	18.1 %	0.0 %	18.4 %
	female	frequency	45	7	59	9	120
		percentage	77.6 %	87.5 %	81.9 %	100.0 %	81.6 %
Age	<30	frequency	34	7	38	0	79
		percentage	58.6 %	87.5 %	52.8 %	0.0 %	53.7 %
	30–40	frequency	19	1	17	3	40
		percentage	32.8 %	12.5 %	23.6 %	33.3 %	27.2 %
	>40	frequency	5	0	17	6	28
		percentage	8.6 %	0.0 %	23.6 %	66.7 %	19.0 %
Experience	<5	frequency	44	8	32	0	84
		percentage	75.9 %	100.0 %	44.4 %	0.0 %	57.1 %
	5–10	frequency	8	0	21	3	32
		percentage	13.8 %	0.0 %	29.2 %	33.3 %	21.8 %
	>10	frequency	6	0	19	6	31
		percentage	10.3 %	0.0 %	26.4 %	66.7 %	21.1 %
Vaccinated	yes	frequency	21	5	45	9	80
		percentage	36.2 %	62.5 %	62.5 %	100.0 %	54.4 %
	no	frequency	37	3	27	0	67
		percentage	63.8 %	37.5 %	37.5 %	0.0 %	45.6 %

The results on respondents' knowledge and attitude are as follow. It is generally known that healthcare workers' knowledge of hospital waste management is fundamental to proper management and is the most important aspect [19]. Responses are categorized into 4 groups according to the respondent's profession: doctors, pharmacists, paramedics and housekeepers, as shown in Table 4.

From the responses obtained, it is possible to find that most workers (89.7 %, 100 % and 61 % of doctors, pharmacists and paramedics respectively) have not attended any training courses on hospital waste management, with the exception of housekeepers. Most respondents had little knowledge of the stages involved in hospital waste management, with 44.8 %, 37.5 % and 47.2 % of doctors, pharmacists and paramedics respectively unable to classify these stages. According to the results, 43.1 %, 50.0 %, 54.2 % and 55.6 % of doctors, pharmacists, paramedics and housekeepers respectively gave an incomplete definition of hospital waste, and 72.4 %, 62.5 %, 84.7 % and 100.0 % of doctors, pharmacists, paramedics and housekeepers did not know the number and types of hospital waste. Thus, most do not know all the color codes, where 55.2 %, 75.0 %, 72.2 % and 100.0 % of doctors, pharmacists, paramedics and housekeepers respectively cited only two or three of the five colors.

Table 4

Knowledge and attitude of healthcare workers on healthcare Waste Management

Results			Doctors	Pharmacists	Paramedics	Housekeepers	Total
1	2	3	4	5	6	7	8
Q1: Have you attended any training courses or scientific days on hospital waste management?	yes	frequency	6	0	28	9	43
		percentage	10.3 %	0.0 %	38.9 %	100.0 %	29.3 %
	no	frequency	52	8	44	0	104
		percentage	89.7 %	100.0 %	61.1 %	0.0 %	70.7 %
Q2: What is the definition of hospital waste?	TRUE	frequency	24	2	12	3	41
		percentage	41.4 %	25.0 %	16.7 %	33.3 %	27.9 %
	partial	frequency	25	4	39	5	73
		percentage	43.1 %	50.0 %	54.2 %	55.6 %	49.7 %
	FALSE	frequency	9	2	21	1	33
		percentage	15.5 %	25.0 %	29.2 %	11.1 %	22.4 %
Q3: Classify these hospital waste management steps in order	TRUE	frequency	17	2	14	5	38
		percentage	29.3 %	25.0 %	19.4 %	55.6 %	25.9 %
	partial	frequency	15	3	24	4	46
		percentage	25.9 %	37.5 %	33.3 %	44.4 %	31.3 %
	FALSE	frequency	26	3	34	0	63
		percentage	44.8 %	37.5 %	47.2 %	0.0 %	42.9 %
Q4: How many types of hospital waste are there?	TRUE	frequency	16	3	11	0	30
		percentage	27.6 %	37.5 %	15.3 %	0.0 %	20.4 %
	FALSE	frequency	42	5	61	9	117
		percentage	72.4 %	62.5 %	84.7 %	100.0 %	79.6 %
Q5: List the types of hospital waste	TRUE	frequency	10	2	1	0	13
		percentage	17.2 %	25.0 %	1.4 %	0.0 %	8.8 %
	partial	frequency	22	3	35	9	69
		percentage	37.9 %	37.5 %	48.6 %	100.0 %	46.9 %
	FALSE	frequency	26	3	36	0	65
		percentage	44.8 %	37.5 %	50.0 %	0.0 %	44.2 %
Q6: What are the different color codes for hospital waste?	TRUE	frequency	8	1	2	0	11
		percentage	13.8 %	12.5 %	2.8 %	0.0 %	7.5 %
	partial	frequency	32	6	52	9	99
		percentage	55.2 %	75.0 %	72.2 %	100.0 %	67.3 %
	FALSE	frequency	18	1	18	0	37
		percentage	31.0 %	12.5 %	25.0 %	0.0 %	25.2 %
Q7: What's the difference between infectious risk waste and household waste?	TRUE	frequency	47	8	48	0	103
		percentage	81.0 %	100.0 %	66.7 %	0.0 %	70.1 %
	partial	frequency	6	0	13	0	19
		percentage	10.3 %	0.0 %	18.1 %	0.0 %	12.9 %
	FALSE	frequency	5	0	11	9	25
		percentage	8.6 %	0.0 %	15.3 %	100.0 %	17.0 %
Q8: What happens if infectious risk waste is mistakenly mixed with household waste?	TRUE	frequency	48	7	53	8	116
		percentage	82.8 %	87.5 %	73.6 %	88.9 %	78.9 %
	FALSE	frequency	10	1	19	1	31
		percentage	17.2 %	12.5 %	26.4 %	11.1 %	21.1 %
Q9: What is the fill limit for waste bags and containers?	TRUE	frequency	37	5	47	4	93
		percentage	63.8 %	62.5 %	65.3 %	44.4 %	63.3 %
	FALSE	frequency	21	3	25	5	54
		percentage	36.2 %	37.5 %	34.7 %	55.6 %	36.7 %
Q10: What is the period not to be exceeded to transport the waste for disposal?	TRUE	frequency	47	8	62	8	125
		percentage	81.0 %	100.0 %	86.1 %	88.9 %	85.0 %
	FALSE	frequency	11	0	10	1	22
		percentage	19.0 %	0.0 %	13.9 %	11.1 %	15.0 %

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Continuation of Table 4

1	2	3	4	5	6	7	8
Q11: What illnesses can be caused by poor hospital waste management?	TRUE	frequency	39	5	33	1	78
		percentage	67.2 %	62.5 %	45.8 %	11.1 %	53.1 %
	partial	frequency	7	0	10	8	25
		percentage	12.1 %	0.0 %	13.9 %	88.9 %	17.0 %
	FALSE	frequency	12	3	29	0	44
		percentage	20.7 %	37.5 %	40.3 %	0.0 %	29.9 %
Q12: What do you think about the different rules of hospital waste management?	good	frequency	52	7	62	9	130
		percentage	89.7 %	87.5 %	86.1 %	100.0 %	88.4 %
	bad	frequency	6	1	10	0	17
		percentage	10.3 %	12.5 %	13.9 %	0.0 %	11.6 %
Q13: What type of container should this waste be disposed of in?	TRUE	frequency	14	5	18	0	37
		percentage	24.1 %	62.5 %	25.0 %	0.0 %	25.2 %
	partial	frequency	35	3	48	9	95
		percentage	60.3 %	37.5 %	66.7 %	100.0 %	64.6 %
	FALSE	frequency	9	0	6	0	15
		percentage	15.5 %	0.0 %	8.3 %	0.0 %	10.2 %

With regard to management rules, more than half of respondents knew the maximum filling limit for containers and the maximum period for transporting waste. Thus, they knew that if infectious risk waste is mistakenly mixed with household waste, the whole is considered as infectious risk waste. It is possible to find that 67.2 %, 62.5 % and 45.8 % of doctors, pharmacists and paramedics are aware of the diseases that can be caused by poor management of hazardous waste. Finally, the attitude of all respondents was good, with 89.7 %, 87.5 %, 86.1 % and 100.0 % of doctors, pharmacists, paramedics and housekeepers saying that everyone must respect the rules and follow the stages of hospital waste management.

Based on the results of the field inspection, the audit and the staff survey, we have highlighted the various possible causes that led to the poor management of hospital waste, using the Ishikawa diagram, Fig. 6.

This has enabled to propose the following solutions, Table 5.

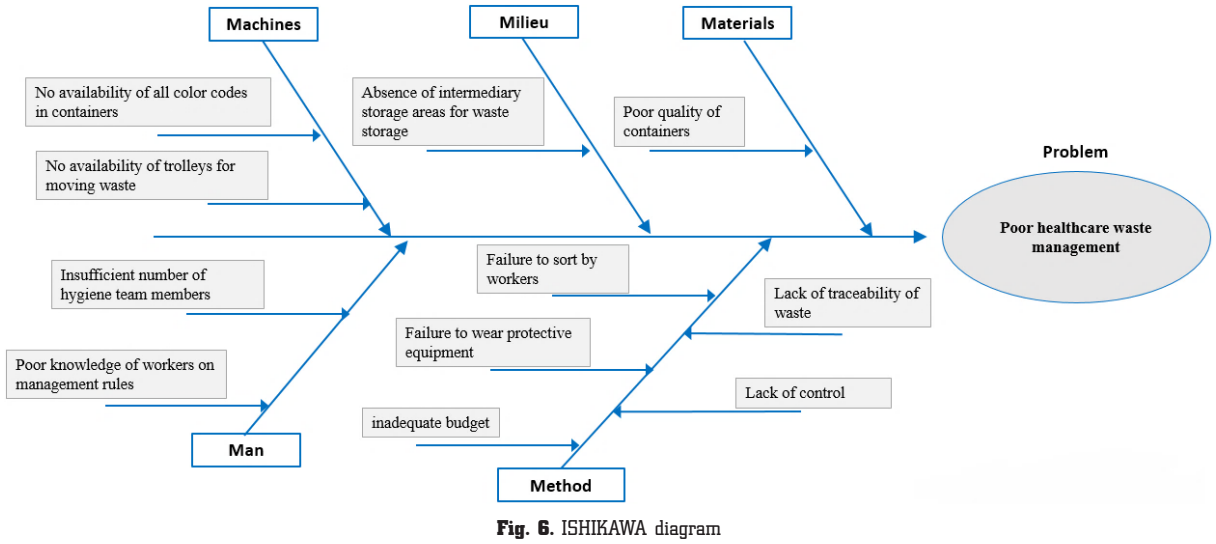

Fig. 6. ISHIKAWA diagram

Table 5

Proposed solutions for each type of malfunction

Type of malfunction	Proposed solutions
Man	– Ensuring worker safety through education, training and awareness-raising. – Build a hygiene team with a sufficient number of members to ensure regular monitoring
Method	– Ensure an adequate budget. – Emphasize sorting and reduction at source. – Provide workers with appropriate personal protective equipment. – Integrate traceability technologies such as RFID to keep track of the quantities of waste produced
Machines	– Ensure safe collection and transportation. – Provide containers with all necessary color codes
Milieu	– Develop an infrastructure for intermediate storage and recycling of hazardous waste
Materials	– Ensure the conformity and quality of different types of containers and equipment

3.3. Practical importance, limitations and prospects for using the research results. The results of this research are of paramount importance for the management of hospital waste. Applying the suggested recommendations can easily reduce harmfulness and nuisances at the level of activities in the different departments, or even improve the efficiency and overall quality of healthcare waste management in the different departments of health and veterinary establishments. The application of this methodology can help hygienist managers to detect gaps in the management of healthcare waste. This makes it possible to implement healthcare waste management programs that respond to the reality on the ground with regard to: the terms and conditions for sorting, processing, handling, storage, transport and destruction of waste, thus leading to more sustainable and profitable operations. Thus, following the methodologies applied and the results obtained in this research, this strategy can be generalized to national and international health and veterinary establishments, provided that the local context and specific conditions are taken into account. However, for establishments in different countries the proposed model can adapt to their unique operational environments, taking into account scientific developments and legislative requirements. It should also be noted that to effectively use the results of this research, certain conditions must be met, namely:

– *data availability*: accurate and complete data on the quantity and types of waste generated by each service;
– *technological infrastructure*: adequate technological infrastructure for each link in the logistics chain;
– *management support*: strong support from relevant stakeholders is crucial for the successful implementation of the proposed strategy;
– *training, awareness and information campaigns* must be encouraged, especially in terms of the notion of risk and preservation of the environment.

As this study was conducted in a single establishment, further studies that include many establishments are necessary for a better assessment of the current situation. This strategy can be extended to other national health and veterinary establishments as it provides valuable information and methodologies to optimize reverse logistics operations.

4. Conclusions

The management of healthcare waste is becoming increasingly important in the field of public health and the environment. This management is crucial. However, we are still obsolete, given that the waste disposal system from healthcare activities is neither organized, nor structured, nor secure in all the services of our studied healthcare establishment. All the actions carried out so far have proven to be faulty and disparate. From now on, the establishment must respect the five fundamental stages of sorting, packaging, storage and transport until treatment which is done by banalization. This interest relates to the multitude of contamination risks and nuisances that can be caused to humans and the environment. Thus, it was found that the least respected stage is warehousing, where no service exceeds 25 %, and this is a very low value. This comes down to the fact that no service has an intermediate waste storage area, and the waste is left either in the corridors or in the toilets. Thus, there is no traceability of hospital waste to calculate the quantity generated. Same thing for the second stage, the conditioning which is also not respected, where it does not exceed 50 %. This is due to non-compliance with the packaging rules required by regulations, where we find, for example, poor quality and non-resistant waste bags. The same findings were raised in the other stages.

As research results, no serious support is undertaken. There is a glaring lack in the management of healthcare waste at the establishment level. Thus, hygienist managers must ensure the establishment of a healthcare waste management program with regard to: the terms and conditions for sorting, processing, handling, storage, transport and destruction of waste. As research recommendations, Table 5 brings together a significant number of solutions. In addition, it is possible to recommend training, awareness and information: especially in terms of the notion of risk (Source of infections and risk of contamination by HIV, hepatitis B or C or other germs), measures of basic hygiene (medical monitoring and vaccination), the issues of good management of sharps waste (brand image of the establishment) and procedures in the event of an incident and accident at work.

However, to assume this responsibility, organizational measures must be taken urgently and immediately by considering the necessary prerequisites for setting up a system for managing this healthcare waste, or even reverse logistics.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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