Original Article

A Survey on the Status of Hospital Waste Management Using Two Methods of Risk Assessment of Failure Modes and Effects Analysis and Preliminary Hazard Analysis

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Abstract

Aims: The growth of population and people's need for health care have increased medical wastes productions. The aim of this study is the hazardous waste risk assessment of hospital by using of two methods: failure mode and effects analysis and preliminary hazard analysis (PHA). **Methods:** The first, worksheets related to fracture mode and effects analysis were distributed among hospital experts and then the potential hazard for the type of wastes was determined. **Results:** At method of failure mode and effects analysis, 8 cases had the risk priority number >100 and according to the results of the PHA, the sharp, infectious, human anatomical, chemical/pharmaceutical, and radioactive wastes, respectively, had a high potential of risk. **Conclusion:** failure mode and effects analysis can be used as a new approach to preventing errors and improving processes with the aim of increasing safety and reducing of probability danger in long term.

Keywords: Failure mode and effects analysis, hospital, medical waste preliminary risk analysis

Introduction

The rapid growth of population and the increasing need of the society to healthcare centers led to the expansion of various health facilities and medical waste productions.[1] Health centers annually generate >2.4 million tons of medical waste.[2] Furthermore, 5.22 million people in the world died as a result of diseases that due. According to the definition of the WHO, infectious waste is a type of pathogenic waste (bacteria, virus, parasite, or fungus) that causes to disease in humans[3,4] and improper disposal of that is a threat to the health of medical staff.[5] Therefore, improper management of medical waste causes to infectious diseases such as typhoid, hepatitis B, C and aids, and so on.[6,7] According to the WHO, more than two million health-care workers face to skin injuries due to sharp wastes each year.[8] In the field of infectious waste, first, proper management in the stages of separation, collection, transfer and disposal, and then effective training and monitoring is very important.[9]

Risk management is an important part of strategic management of health care.[10] There are several methods for medical waste risk assessment, including preliminary hazard analysis (PHA)/preliminary risk analysis, failure mode and effect analysis (FMEA), fault tree analysis, and so on. The preliminary risk analysis method is used as the first step in risk assessment processes. Preliminary risk analysis is performed by identifying risk and prioritizing according to the probability of an event or injury.[11] Failure mode and impact analysis can be used as a powerful tool for system safety and reassuring of engineers for identifying critical parts whose failure leads to adverse outcomes such as loss of production.[12] Risk management has an important role in the accreditation of standards in hospitals and its sections to patients and staff's safety. In recent years, many studies

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have been conducted to the medical waste risk assessment in Iran and other countries using by FMEA and PHA methods.[11,13-18] The results of these studies have shown that monitoring and modifications in some management methods are necessary to reduce the environmental impact of hospital waste. Furthermore, the high rate of production of infectious waste indicates creating standards and principles rules for medical waste management is important. The main of this study is hospital waste risk assessment by use of failure mode and effects analysis and PHA methods.

Materials and Methods

In this study, we used two methods of risk assessment. FMEA and PHA to check the status of hospital waste management.

FMEA method:

1. At first, a specialized team formed with expertise related to the management. Team members consisted of environmental health, waste management, infection control experts, responsible for engineering and occupational health experts
2. The next step, the team members were presented a description in the implementation of FMEA
3. At this stage, the team members were asked to list them according to their expertise errors and potential failure modes that may occur since the separation to disposal stage of hospital waste for service and waste autoclave device users. The team members have raised the potential risks and recorded in the worksheet FMEA
4. The effects and cause of each risk were examined by each member
5. Each of the members offered to each of the listed risk ratings between 1 and 10, according to the criteria of severity [Table 1], occurrence [Table 2], and detection [Table 3] in the worksheet FMEA, which expressed the importance and measured each of these numbers
6. Then calculated the risk priority number (RPN) (multiplication ranking in the columns of severity, occurrence, detection) according to the most frequent. Prioritize failure modes were calculated after RPN for each process step. The RPN was calculated by using the following formula:[14] RPN = S × O × D
7. This study was conducted in RPN >100, including failure mode and improper situations discovered.[13]

Preliminary hazard analysis method

In risk assessment, PHA was used to identify, describe and prioritize risks based on the severity [Table 4] and occurrence [Table 5] of hazardous waste produced in hospital and finally were offered preventative methods associated with this type of waste.

PHA has been widely applied in industrial risks, our study attempted to apply for risk related to health-care waste.[19]

Table 1: The criteria of severity of failure mode and effect analysis[13]

Effect	Criteria: Severity of effect	Rank
Catastrophic	Death of individual or complete system failure	10 9
Major injury	Major injury of individual or major effect on system	8 7
Minor injury	Minor injury of individual or minor effect on system	6 5
Moderate	Significant effect on individual or system with full recovery	4 3
Minor	Minor annoyance to individual or system	2
None	Would not affect individual or system	1

Table 2: Failure mode and effect analysis suggested occurrence evaluation criteria[13]

Probability of failure	Failure rates possible failure probability/number of operating days	Rank
Very high	<1:2	10
Very high	<1:10	9
High	<1:20	8
High	<1:100	7
Moderate	<1:200	6
Moderate	<1:1000	5
Relatively low	<1:2000	4
Low	<1:10,000	3
Remote	<1:20,000	2
Remote	<1:20,000	1

Table 3: Failure mode and effect analysis suggested detection evaluation criteria[13]

Detection	Criteria (%)	Rank
Absolute uncertainty	0–5	10
Very remote	6–15	9
Remote	16–25	8
Very low	26–35	7
Low	36–45	6
Moderate	46–55	5
Moderately high	56–65	4
High	66–75	3
Very high	76–85	2
Almost certain	86–100	1

The risk location is then determined from the risk assessment matrix [Table 6]. Furthermore, the study was conducted in a period of 1 month, weighing hospital waste on a daily basis in order to determine the most hazardous waste producers.

Finally, according to the severity and occurrence tables, PHA Worksheet recorded information and were determined matrix risks related to waste management.

Results

The accident is an unforeseen event which leads to interruptions in normal activities that is possible accompanied by physical and psychological injuries or financial losses. In FMEA, failures are prioritized according to how serious their consequences are, how frequently they occur, and how easily they can be detected. The purpose of the FMEA is to take actions to eliminate or reduce failures, starting with the highest-priority ones. According to the application method FMEA in the hospital waste management, 11 failure mode to recognition since separation to waste disposal. In 11 failed to identify the eight failure mode has a higher RPN 100 and classified as the priority failures and need to recommended actions and their control. With due attention to RPN for failure mode, to determine a mode improvement order that respiration injury, skin, Physical, muscular Injury, needle stick, waste error discard, explosion steam boiler, lack of person for carrying waste, plant operation, electrical shock due work with set, damage waste autoclave and chemical/pharmaceutical waste determine as the priority cases, respectively. For example, at system function handling and collecting, storing and waste safety; failure mode including respiratory injuries and effects nonobservance including tuberculosis, brucellosis, vocation, asthma, severe acute respiratory syndrome, susceptibility respiratory that the RPN 294 and recommended actions are included use from nature or mechanical ventilation, respiratory keeping with the filterable mask, do not leave waste long in-store place, to dilute chemical material.

Collect data for identified failure modes using brainstorming eight expert authorities in this hospital are obtained in Table 7. Risk assessment with the PHA method is presented in Table 8.

Table 4: Severity of consequence criteria[19]

Type of effect	Type of injery
No effect (1)	Has no effect on health
Minor (2)	Minor injury
Major (3)	Major injury
Hazardous (4)	Serious or fatal injury
Catastrophic (5)	death

Table 5: Possibility occurrence preliminary risk analysis

Likelihood of occurrence	Hazard severity
Very unlikely (A)	Does not exist
Unlikely (B)	Little
Possible (C)	There is likely
Likely (D)	The probability for several times
Very likely (E)	The likelihood is frequently

Discussion

The risks in all medical centers are due to internal or external factors. Risk management in hospitals has an effective role in the prevention of occupational accidents and the creation of staff's safety. According to the implementation of safety analysis with FMEA method in the studied hospital, from the separation stage to the disposal waste, 11 failure modes was identified. Eight items of these have an RPN higher than 100 and should be classified as the priority failures that needed to recommended and controlled measures. In similar studies, a study of safety analysis in the Indian hospitals using by FMEA method in the stages of production to disposal wastes was done. In the separation of medical waste and transfer them, the RPN were more than 500 and 200, respectively, which is unacceptable and undesirable.[9] A study of Bandar Abbas Hospital in southern of Iran identified 42 RPN. Among the identified risks, 29% were low and 71% were medium.[20] According to PHA and risk assessment matrix in hospital waste management system, Sharp waste, infectious, (human anatomical, chemical/pharmaceutical, pressure), radioactive waste, electrical should be in high risk respectively.[18] In a study conducted in three hospitals in Portugal, the results showed that the workers of the section of transfer wastes and they who are in contact with sharp wastes, are at a high level of risk.[21] The sharp wastes caused to cut the skin and infectious.[8] Therefore, all personnel needed to training about this.[11] Many of the chemical/pharmaceutical wastes used in medical centers are dangerous. The chemical/pharmaceutical wastes can cause to poisoning acute, chronic or physical injury. The most common of which is chemical burns. The risks of radioactive wastes are different according to the type and amount of their dose. Some of these risks include to headaches, dizziness, and vomiting.[8]

Conclusion

The greatest risk occurs as a result of poor management of sharp waste, infectious waste and the anatomical, chemical/

Table 6: Risk assessment matrix

	Hazard severity				
Likelihood of occurrence	No Effect (1)	Minor (2)	Major (3)	Hazardous (4)	Catastrophic (5)
Very Unlikely (A)	Low	Low	Low	Low	Medium
Unlikely (B)	Low	Low	Low	Medium	Medium
Possible (C)	Low	Low	Medium	Medium	High
Likely (D)	Low	Medium	Medium	High	High
Very Likely (E)	Low	Medium	High	High	High
Low risk	Medium risk		High risk		

Table 7: Failure mode and effect analysis related to hospital waste management

System function	Failure Mode	Effects	Severity	Occurrence	Failure cause
Handling and collecting, storing and waste safety	Respiratory injuries	TB, brucellosis, vocation, asthma, severe acute respiratory syndrome, susceptibility respiratory	7	7	Check use from Personnel protective equipment, fit ventilation in waste temporary store room, daily wastes collecting and transport, to dilute proper chemical material according to manufactory for with less poisonousness
Waste handling and collecting	Skin injuries	Diseases transfer with person, personal active efficiency decrease providing contamination, person remedy expense increase and using expense and time for new personal training, skinny sensibility, agitation and skin and eye irritation, skin burnt due confronting set steams	7	7	Use personnel protective equipment (gloves, mask, shield), personal vaccination, standard cautionary actions (local continuous washing with much water, no recapping of needle, promotion hand proper hygiene)
Waste handling	Skeletal, muscular and physical injury	Lumbago, muscular pain, stress with loins and neck spinal column, behind injury, vertigo, headache, fatigue, drowsy, falling, stroke with head, to be disillusioned	7	7	Survey burden transfer decrease by person, use automatic trolley for waste handling with truck, more person recruitment due to replace, don't application responsibility one person for several place
Separation, waste handling and collecting	Needle stick	Infection with HBV, HBC, HIV and other blood infections	8	10	Use personnel protective equipment (industrial boots, industrial apron and heavy labor gloves and mask, hat), personal vaccination, standard precautionary actions (no recapping of needle, promotion hand proper hygiene)
Waste separation	Personal, Patients and their families discard in error	Increase infectious waste volume, sharp waste in other wastes and increase needle sticking, increase set function and decay that probability, existence other drugs in infectious waste and probability explosion.	7	8	Survey training in separation, use colored bins for waste separation, check labeling, regular and repeated control from units, check to install poster and signs for increase notice
Central waste room	Explosion boiler	Explosion boiler and life casualty	8	7	Survey performance periodical training due notice increase about boiler and them hazards, inform in-time set and boiler decay
Collecting waste from origin local to central site	Lack person for waste collecting	Infectious transfer to others, creation pressure and stress due lack enough personal, decrease performance waste management laws	2	7	Survey condition waste handling, survey wastes transport route, notice units responsible don't allocate other persons for waste handling
Disposal	Operation evanescence	Contaminated other wastes, transfer contamination to persons, water, air and soil	7	6	Survey mechanical (heat, pressure, time), boovidick, chemical and biologic tests dependent to set type
Waste evanescence central	electric shock due work to set	Burn, physical injury, death	8	6	Use personnel protective equipment, periodical survey facilities wire and sets by center electrical engineer
Waste evanescence central	Decay Waste evanescence	To leave waste in central room and odor production, contamination and insects, skinny and respiratory injury due don't waste autoclaving, emulsion and ichor production due set decay	5	6	Quick cooperation and coordination with respective company due set repair, creation punishment condition or cancel convention with guilty persons
Final transport and temporary storing	Chemical-pharmaceutical waste	Don't preparation several company in country due collecting Chemical- pharmaceutical waste, obligation waste collected and no preparation room	Odor and emulsion production, headache, nausea, eye combustion, skinny symptoms	4	7

Contd...

Table 7: Contd...

System function	Factors	Detection	RPN (S × O × D)	Improvement order	Recommended actions
Handling and collecting, storing and waste safety	Lack notice from disease transfer through respiration wastes containing blood and excretions and drugs residue Lack use from mask Use disinfectant chemical products.	6	294	1	Use from nature or mechanical ventilation, respiratory keeping with filterable mask, don't leave waste long in store place, to dilute chemical material
Waste handling and collecting	Lack notice from disease transfer through wound or open injury, lack regard hand hygiene, Lack notice from waste proper handling, lack use from personnel protective equipment, Lack notice from confronting with steam exit from evanescence set	5	245	2	Personal training, Regard hand hygiene, cautionary actions regard with set, enforce use personnel protective equipment
Waste handling	Lack notice from heavy burden transfer, lack person and doing several hour continuous work, increase active volume and several responsibility persons, little economic condition persons	5	245	2	Training to raise proper heavy burden, several stages wastes transfer for burden decrease, use from aid person, need work time performance according to basic standard for increase efficiency active
Separation, waste handling and collecting	Lack notice from existence sharp waste, high active volume, waste carrying personal carelessness in do not use personnel protective equipment, to tread waste, inobservance in sharp waste disposal and no recapping of needles after use	3	240	3	Training and actions whereas needle stick, don't tread wastes and no recapping of needles after use, forcing to use personnel protective equipment
Waste separation	Wastes mixture together	3	168	4	Training for separation in origin, labeling, regular and repeated control from units, poster and signs installation in units for increase notice
Central waste room	Don't survey period, don't survey boiler function, inattention with alarm and to stopping set door, no presence side set	3	168	4	Period survey due set proper function, attention with alarm signs due set irregular function, referring to experts
Collecting waste from origin local to central site	Don't acceptance person due collected, several efficient waste handling personal, work high volume in units	6	126	5	Recruitment persons enough number, training for waste proper transport, to inform units responsible due don't allocate other persons for waste handling
Disposal	Don't tests, don't calibration	3	126	5	Do tests according waste management laws, do calibration, training operators, waste delivery and receipt by respective company, periodical survey by respective organizations due set operation correctness consider, send tests results to respective centers
Waste evanescence central	Don't existence politics due set periodical survey, operator notice lack of technical actions due error in-time distinction, carelessness in fault removal	2	96	6	Training, use personnel protective equipment, referring to experts
Waste evanescence central	Use continuous from set, set periodical don't survey by manufacture company, waste high input volume to set, operators carelessness in use daily set due pressure decrease in set	3	90	7	Creation policy due set periodical survey, decrease waste remain time in central temporary room
Final transport and temporary storing	3	84	8	Preparation company with official justification for in-time collecting Chemical- pharmaceutical waste, construction separate room for wastes type, use powerful ventilation, use particulate masks	Check use particulate masks, repeated following with respective company due wastes transport

RPN: Risk priority number, HBV: Hepatitis B virus, TB: Tuberculosis, HVI: Human Immunodeficiency Virus

Table 8: Preliminary risk analysis applied for waste management hospital

Hazard healthcare waste	Transmission vehicles	Accidental events	Preventive actions	Likelihood of occurrence	Severity
Infectious waste	Contact- inhalation and droplets, mucus coat‹ Ingestion	Infection (HIV, viral hepatitis, brucellosis, typhoid fever, enteritis, cholera, TB, anthrax, TB‹ severe acute respiratory syndrome and etc.	Collected in yellow bags or containers for infectious waste and should be marked with the international infectious substance symbol Use of appropriate personnel protective equipment. Creation strong job plan, proper design for collecting, transfer and disposal infectious waste	C	5
Sharp	Punctures -cuts, Infect the wounds	Injury and HBV infectious, HCV, HIV and other blood infectious	Collected in rigid containers (safety box). Vaccination against HBV. Use of appropriate personnel protective equipment. Creation strong job plan, proper design for collecting, transfer and disposal sharp waste. Develop written work and emergency procedures	D	5
Pharmaceutical and chemical waste	Absorption through skin, mucus coat, inhalation, ingestion	Poisoning, physical injury and burn, skin, eye and mucus coat injury, respiratory danger	Collected in white or brown bags separate than other wastes, separate collection other pharmaceutical wastes that have more contaminate danger in production point, use of appropriate Personnel protective equipment, replace and use from chemical materials with less danger, use from proper ventilation in chemical material keeping depot, training personnel for prevention actions and emergency treatment in accident cases	C	4
Human anatomical waste	Contact	Infectious	Collected in yellow bags, use of appropriate personnel protective equipment, develop written work and emergency procedures	C	4
Radioactive waste	Contact	Headache vertigo and vomiting, radiation and injury cells unrvocable, anemia, blood cancer, lung cancer as the result of inhalation sting ray	Collected in yellow bags, sealed, marked and indicated with the international radioactive symbol. Use of appropriate personnel protective equipment, Develop written work and emergency procedures	B	5
Electric	Contact inhalation Ingestion	Skin Inflammation diseases, respiratory mechanism annoyances and injury to lungs, cancer, digestion diseases, Effect on nervous system, brain and etc.	Use from human sources and dry wastes collection machine (paper, plastic, and glass) for collection waiving electrical equipment, to allocate local in city area salvage stations for electronic wastes, creation centers for acceptance electronic waiving facilities in units that is repairmen and salesmen electronic waiving equipment concentration local	B	4
Pressurized containers	Contact on brunt	Damage, explosion danger because of wisdom or to unessential crush	Collected in the local away from un responsible people accessible, burial in a sanitary landfill, delivery with salvage authorized centers	C	4

HBV: Hepatitis B virus, HCV: Hepatitis C virus, TB: Tuberculosis

pharmaceutical, and radioactive. If possible, the best practice to prevent the risk of medical wastes, to minimize hazardous waste center. The medical staff should consider the proper disposal of medical waste as part of the treatment. On the other hand, it seems necessary to carry infectious waste and sharp trolleys to collect after treatment in a patient's room and the location of infectious bags and sharp should be close to the nursing or treatment room and takes away from patient access. In this study, the FMEA method was introduced as a new approach to the prevention of errors and improve processes to increase safety. FMEA is based on the assumption that things could be faced with error; so it seems that the risk management methods of analysis are very costly and time-consuming, but in the long term by reducing multiple potential accidents can be reduced adjustment costs. Furthermore, use PHA and Risk matrix analysis for determining high level of risk wastes. Similar research to be offered to identifying other risks and determining appropriate approaches.

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Ethics code

N. IR.TUMS. REC.1394.141.

Conflicts of interest

There are no conflicts of interest.

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