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MEDICAL WASTE MANAGEMENT

H.M. Bagirova, Prof. F.G. Aliyev

Azerbaijan University of Architecture and Construction, Baku, Azerbaijan

humayb09@gmail.com

Azerbaijan University of Architecture and Construction, Baku, Azerbaijan

ie_academy@yahoo.com

Abstract: In the modern healthcare system, the expansion of medical services has led to an increase in both the volume and the hazard level of generated waste. Medical waste differs from municipal waste in its composition, as it includes infectious materials, sharps, pharmaceutical residues, chemical substances, and other hazardous components. For this reason, the proper segregation, safe transportation, and appropriate treatment of such waste are of great importance for environmental protection and the safeguarding of public health. In this article, the main stages of medical waste management in healthcare institutions are analyzed from an ecological perspective, while the key shortcomings in segregation practices, the risks arising during transportation, and the main characteristics of treatment methods are summarized. The study shows that the initial segregation stage plays a decisive role in ensuring the safety of the entire management system. At the same time, the proper organization of in-house logistics, the establishment of temporary storage conditions in compliance with regulatory requirements, and the improvement of staff training significantly contribute to the reduction of environmental and sanitary risks. It has been determined that a systematic approach to medical waste management not only helps prevent environmental pollution but also creates the foundation for a safe management model within healthcare institutions.

Keywords. Medical waste, waste management, healthcare institutions, environmental safety, treatment.

1.Introduction

In the modern era, waste management is regarded as one of the most pressing issues in the field of environmental protection. The expansion of production, consumption, urbanization, and the service sector has led to an increase in the volume of various types of waste. Among these, medical waste occupies a special place. This is because such waste differs not only in terms of quantity but also in terms of its hazardous characteristics. Waste generated in healthcare institutions includes infectious materials, used syringes, needles, dressing materials, laboratory residues, chemical reagents, and pharmaceutical substances. The uncontrolled

collection of these materials or their mixing with other types of waste poses a serious threat to both human health and the natural environment.

The issue of medical waste management should be considered not merely as a sanitary matter, but as a complex problem closely related to environmental safety, public health, and management efficiency. When such waste is not properly segregated, appropriately packaged, and transported through safe routes, the likelihood of adverse effects on soil, water, and the atmosphere increases. In particular, the mixing of infectious waste with general municipal waste further intensifies the risk at subsequent stages of handling. In such cases, the negative impact of waste extends not only within healthcare facilities but also beyond them.

In recent years, the widespread use of disposable medical items in the healthcare system has altered the structure of medical waste and made its management more complex. Disposable gloves, masks, protective clothing, injection materials, and various plastic-based medical supplies become waste after use, thereby increasing the volume of the hazardous fraction. This, in turn, strengthens the need not only for the collection of medical waste, but also for its step-by-step management. [1–3]

The segregation of medical waste in healthcare institutions represents the most important initial stage of the management system. Proper classification of waste at the moment it is generated provides the basis for the safe and efficient organization of subsequent processes. If hazardous waste is mixed with other waste streams at the initial stage, both the burden of treatment and the risks of infection and contamination increase. The transportation stage is also of considerable importance in medical waste management. Waste must be transferred from the department where it is generated to the temporary storage area, and then to the subsequent treatment or disposal stage, under controlled and safe conditions. Otherwise, leakage, spillage, accidental contact, and uncontrolled spread may occur. Treatment is one of the final and most responsible stages of medical waste management. The aim at this stage is to reduce the hazardousness of the waste and to minimize the threat it poses to human health and the environment. It is essential to select different treatment methods for different categories of waste.

The main objective of this article is to analyze the processes of segregation, transportation, and treatment of medical waste in healthcare institutions from an ecological perspective, to summarize the main problems arising at these stages, and to substantiate the importance of safe management. [2–6]

2. Experimental detail

During the study, the medical waste management system was examined through a step-by-step approach using a healthcare institution as a representative example. The main objective of the research was to evaluate, from an ecological perspective, the sources of medical waste generation, the characteristics of its segregation, the sequence of its transportation, and the methods applied for its treatment. At the initial stage, the principal sources of waste generation within healthcare facilities were identified. These included procedure rooms, surgical departments, laboratories, vaccination rooms, patient wards, treatment rooms, and auxiliary administrative areas. It was determined that each of these areas generates waste of different composition and varying levels of hazard. [7–8]

Within the methodological framework of the study, waste was first classified according to its hazard level and origin, and then its actual management trajectory was followed. This approach made it possible to analyze the entire chain through which the waste passes, from the point of generation to the subsequent stages of handling. During the research, the main types of medical waste and their possible sources of generation were summarized as follows (Table 1).

Table 1. Main types of medical waste and their sources of generation

Type of medical waste	Main source of generation	Brief characteristics
Infection waste	Wards, procedure rooms, laboratories	Waste contaminated through contact with biological fluids and infection materials
Sharps waste	Infection rooms, surgical departments, laboratories	Needles, scalpels, broken ampoules
Pathological waste	Surgical and specialized medical intervention areas	Tissues, organs and biological body parts
Pharmaceutical waste	Treatment rooms, pharmacy units	Expired medicines and pharmaceutical residues
Chemical waste	Laboratories, disinfection areas	Reagents, disinfectants and chemical residues
General municipal-type waste	Administrative and auxiliary areas	Paper, packaging materials, food waste

At the next stage of the study, the main stages of waste management were examined separately. These stages included on-site segregation, packaging, in-house transportation,

temporary storage, and treatment. Each stage was assessed from ecological and sanitary perspectives, and the points carrying potential risk were identified.

At the on-site segregation stage, the main objective was to demonstrate the importance of assigning waste to the appropriate category from the moment it is generated.

At the packaging stage, special attention was paid to the principle of using containers and bags appropriate to the type of waste. In particular, the importance of puncture-resistant containers for sharps waste and leak-proof bags for infectious waste was emphasized. In this context, packaging was considered not only as a means of storage, but also as a tool for safety and information. [9, 10]

At the stages of transportation and temporary storage, the main evaluation criterion was the prevention of accidental contact of the waste with both humans and the environment. The proper planning of internal transportation routes, the organization of storage areas under controlled conditions, and compliance with hygienic requirements were regarded as important factors in reducing risk. The table below presents the main stages analyzed in medical waste management and their functional roles (Table 2).

Table 2. Main stages of medical waste management

Stage	Description	Main purpose
On-site segregation	Selection of waste by category at the moment it is generated	To prevent mixing of waste
Packaging	Collection of waste in appropriate bags	Safe collection and transportation
In-house transportation	Transfer of waste from the department to the storage area	To reduce the risk of spread and contact
Temporary storage	Safe short-term storage of waste	To minimize biological and sanitary hazards
Treatment	Selection of an appropriate treatment method according to the type of waste	To reduce the level of hazard

In the experimental section, the treatment methods applied to medical waste were also considered from a comparative perspective. Autoclaving was accepted as one of the main

approaches for the treatment of infectious waste, disinfection methods were applied to certain liquid and chemical wastes, and appropriate incineration methods were regarded as the principal option for high-risk and pathological waste. In this context, not only the technical but also the ecological aspects of each method were taken into account. This is because, if the waste destruction process is not carried out properly, it may itself become a source of secondary pollution. [11]

3. Results and discussion

The conducted analysis demonstrates that the effectiveness of the medical waste management system in healthcare institutions primarily depends on proper segregation. Assigning waste to the appropriate category at the moment of its generation directly affects the safe and efficient organization of the subsequent stages. If the initial segregation is not carried out correctly, infectious, sharps, and other hazardous waste streams become mixed with general municipal-type fractions, thereby increasing both ecological and sanitary-epidemiological risks.

The results under discussion show that the stages creating the greatest risk in medical waste management are segregation, packaging, and temporary storage. In particular, the collection of sharps waste in inappropriate containers increases the likelihood of injury and infection. [4–6]

The findings of the study also indicate that in-house transportation is often regarded as a secondary technical stage; however, in reality, it carries a high hazard potential. If waste is not transferred from departments to the temporary storage area through an appropriate route and if the transportation equipment does not meet safety requirements, the risks of contamination and accidental contact increase. In this respect, the proper organization of the transportation stage should be considered not only a matter of logistics, but also an issue of ecological and sanitary safety.

The discussion of the results makes it clear that the ecological impact of medical waste appears in both direct and indirect forms. The direct impact is associated with the release, leakage, or improper treatment of waste into the environment. The indirect impact is related to the weakening of sanitary conditions within healthcare institutions, the negative effect of waste on surrounding residential areas, and the transfer of the pollution burden to the broader ecosystem. For this reason, medical waste management should be approached not merely as an internal healthcare facility issue, but as a broader matter of environmental safety. The main risk directions at different stages of medical waste management are presented in the following table (Table 3).

Table 3. Main risk directions in medical waste management

Stage	Main risk	Direction of impact
On-site segregation	Mixing of waste	Increase in the volume of hazardous waste
Packaging	Leakage and puncture	Infection and physical injury
Storage	Long-term and uncontrolled storage	Increase in biological activity and odor
Transportation	Inappropriate route or transport means	Risk of contamination and spread
Treatment	Inappropriate method selection	Failure to completely eliminate the hazard

Thus, based on the obtained results, it can be concluded that the main priorities for the safe management of medical waste are proper initial segregation, safe packaging, controlled internal logistics, an appropriate treatment method, and well-trained personnel. It is precisely the integrated implementation of these elements that forms a more sustainable and environmentally safe model of medical waste management in healthcare institutions. [8–10]

4. Conclusion

The conducted study shows that the proper management of medical waste in healthcare institutions is of great importance for ensuring environmental safety and protecting public health. Since medical waste differs from other types of waste in terms of both composition and hazard level, its management requires a specific approach. In particular, the improper segregation of infectious, sharps, pharmaceutical, and chemical waste may not only worsen sanitary conditions within healthcare institutions but also create additional risks for the environment.

In this article, the main stages of medical waste management—segregation, packaging, transportation, temporary storage, and treatment—have been analyzed from an ecological perspective. It has been determined that among these stages, the most important and decisive one is the proper separation of waste at the moment it is generated. When initial segregation is carried out correctly, risks at subsequent stages are reduced, and management becomes safer as well as more economically efficient.

The results of the study indicate that the main problems encountered in medical waste management are related to inappropriate packaging, the inaccurate organization of transportation routes, weak storage conditions, and the insufficient level of staff training. These shortcomings increase the likelihood that harmful effects will be transferred both to humans and to the natural environment.

Thus, for the safe management of medical waste, it is essential to implement a unified and systematic approach, establish infrastructure in accordance with regulatory requirements, ensure the continuous training of staff, and strengthen control mechanisms. Measures taken in this direction not only improve the level of safety within healthcare institutions but also contribute to the prevention of environmental pollution.

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