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Natural Hazards and Their Environmental Impact: Flood Risks in the Systemic Management of Non-Hazardous Municipal Waste

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Abstract: Effective waste management poses a significant challenge for transitional countries, particularly in the context of limited financial and material resources. In Bosnia and Herzegovina (BiH), the inefficiency of the waste management system at both the entity and national levels exacerbates the difficulty of establishing an integrated system resilient to natural and other hazards. This study introduces a theoretical model of comprehensive waste management (CWM) tailored for crisis situations, aiming to advance the development of a unified system across BiH. Key measures proposed include the involvement of key stakeholders, optimization of material resources, and continuous education to address irresponsible waste disposal practices and non-compliance with regulations. These issues contribute to the proliferation of illegal landfills and heighten the risk of large-scale environmental catastrophes. Specifically, in the Republic of Srpska, one of BiH's two entities, 400,000 tons of municipal waste were generated in 2020, averaging 0.95 kg per person per day, with approximately 40% being organic waste and another 40% packaging waste. Regrettably, only about 5% of this waste is recycled, largely due to an inadequate strategy and systemic approach to waste management, with about 30% of the population still lacking access to waste collection services. The proposed CWM model and the associated measures are crucial for mitigating the impacts of natural hazards, such as floods, on waste management systems.

Keywords: Natural hazards; Comprehensive waste management; Floods and natural disasters; Municipal logistics; Shredders and heavy utility machines; State and local community; Management and small and medium-sized enterprises

1. Introduction

Even the developed countries of the world, which constantly invest in infrastructure development, innovations and so on, are susceptible to erosion of both their economic and ecological systems. This is precisely because they do not always give their maximum effort in the field or fail to fully understand the seriousness of potential disasters (such as earthquakes, tsunamis, floods and others) for the economy. Therefore, all the aforementioned hazards are unpredictable in timing and cannot be influenced at the moment of a potential disaster. However, a solid foundation can be created by educating people on behavior before and after such ecological disasters. A disaster can be defined as the impairment of the functioning of a society or broader community due to various types of threats to human lives, material and economic damage, and ecological harm, ultimately affecting environmental stability. Large-scale disasters lead to the declaration of emergencies, which occur depending on the financial stability of the country, i.e., whether it is economically rich or poor.

In terms of globalization and the changes it brings, natural hazards are not what they were 50 years ago compared to today. Climate change, along with the increased effect of greenhouse gas emissions, and all the natural disasters that constantly occur, are a result of people and their irresponsibility towards nature and the environment. Take BiH over the past 10 years, for example. Winters are milder and warmer, with fewer cold periods characterized by

cold mornings and temperatures of -15 or -20°C. In addition, the snow is less frequent and has become a rare occurrence in recent years. This change also brings about the development of a large number of bacteria and viruses, causing illnesses among residents, often with fatal outcomes.

In inland areas, floods can last from several hours to days and are caused by multiple factors, such as heavy rainfall in a short period, rising water levels, etc. Therefore, one of the potential issues that contributes to natural hazards like floods is the human factor. Human behavior towards the environment predicts what kind of future awaits us. Irresponsible disposal of municipal waste by inertia in outside waste bins, i.e., designated containers, leads to not only the deterioration of the environment but also numerous viruses and diseases, to which people are generally not immune.

Therefore, a theoretical model of waste management in crisis situations was proposed in this review paper, which highlights the behaviors of all stakeholders in the chain directly related to systemic waste management and compliance with legal principles. This study aims to address the issues faced by transitional and predominantly poorer countries, which collectively struggle due to behaviors that go against nature and its principles, thus acting contrary to regulations and against their own interests. This actually means that they do not comply with legal regulations regarding waste management, resulting in waste ending up in various places (rivers, forests, roadsides, etc.), and creating illegal landfills that endanger the environment and, as emphasized several times, pose a threat to public health and create unsuitable living conditions for all citizens.

2. Literature Review

Japan, as well as the rest of Asian countries, is an extremely seismically active region, prone to frequent earthquakes and tsunamis. Therefore, greater attention should be devoted to preventive measures seen as precautionary measures, comparing them to gray swans rather than black ones and the hazards they entail (Stein & Stein, 2012). The largest global disasters of modern history, such as earthquakes in Asian countries followed by tsunamis, caused significant material damage but, even more profoundly, thousands of human casualties. Some researchers believe that certain groups of people have recognized the severity of the situation and accepted evacuation, while others lack sufficient solid evidence, i.e., information on the potential fatalities and extensive material damage. Improved communication regarding earthquake warnings and advancements in science can contribute to rescuing people in the future, which will be significantly greater than today, as well as avoiding material damage (Ando et al., 2011). What is the probability that by 2030 a country will be hit by an earthquake, for example, of magnitude 6.7, causing unimaginably large material damage? It is very difficult to forecast these and similar questions because it requires not only studying various geological maps, consulting numerous experts, and considering various geodetic and seismic situations, but also underlining that it is impossible to predict this phenomenon. However, a greater contribution can be made before and after potential earthquakes and similar natural phenomena that cause these disasters (Freedman & Stark, 2003). Developed countries around the world have been making significant financial efforts to build new infrastructure (residential and commercial buildings, bridges, etc.) that is resilient to earthquakes, tsunamis and other similar hazards. Earlier, this was only sporadically and discreetly discussed, but experiences from previous natural disasters have raised this bar to a higher level (Hebden & Stein, 2009).

Natural disasters generate a significant amount of waste, which not only threatens human health due to potential viruses but also disrupts environmental balance in the long term (Cheng et al., 2017). An interesting study emerged in Italy where artificial intelligence can predict the amount of waste generated annually based on potentially known input parameters and machine learning models. However, can it predict or accurately indicate the amount of waste that will occur in a specific area due to a natural hazard, such as a flood or an earthquake (Di Pasquale, 2021)? A significant environmental preservation challenge is posed by sanitary landfills for solid waste disposal, especially in conditions of unpredictable external factors such as earthquakes and floods, which contribute to soil erosion and environmental pollution. Therefore, special emphasis needs to be placed on factors that can be predicted (geological) compared to those that cannot be predicted (e.g., natural hazards) (Huang & Fan, 2016). According to numerous studies carried out worldwide, it is concluded that the developed countries of the world possess waste incinerators, where waste is treated in an environmentally defined manner, compared to transitional countries that mostly lack waste incinerators or have a negligible number of them and simply dispose of waste using basic landfill methods, which pollutes the environment and represents a potentially serious long-term health problem for residents (Keppert et al., 2012; Novarlić & Đurić, 2024; Xiang et al., 2020; Zhao, 2017).

Well-managed sanitary landfills represent one of the most important components of CWM, with a particular emphasis on a healthy living environment and human health (Tang et al., 2015). According to research conducted in China, solid municipal waste volume is reduced through incineration, thereby alleviating pressure on sanitary landfills, and promoting a healthy living environment for a significantly large population (Dou et al., 2017). This can be further interpreted by reducing health risks for residents in the observed area in the event of natural hazards, as well as minimizing any potential environmental risk posed by sanitary landfills (Allegrini et al., 2014). Studies have also shown that by incinerating appropriate materials intended for incinerators instead of simply disposing

of them in landfills, the ash produced can be used as a binding material in road construction, thus creating a desirable option known as the "zero waste" principle (Aberg et al., 2006; Lidelow & Lagerkvist, 2007).

A study conducted in Slovenia has shown that, instead of being influenced directly, floods can be influenced indirectly (preventively) through various forms of education and behavior of the population in accordance with legal regulations as previously mentioned, as well as by the involvement of all stakeholders in the observed area, who are all residents of the same area (Orožen Adamič, 1992). According to research conducted in Serbia, floods represent the greatest material and ecological consequences, serving as a red alert for declaring a state of emergency and involving numerous stakeholders such as the civilian population and the Ministry of Internal Affairs (civil sector and mechanization) (Đorđević, 2017). Research conducted on the banks of the Danube in Budapest, Hungary, used modern materials, which demonstrate the stability of hydrotechnical structures. However, it can be extremely dangerous if not treated with "the care of a good host." It is essential to think globally but act locally to prevent floods, as shown by previous research (Major, 2016).

Various types of hazardous municipal waste that end up in regional sanitary or unsanitary landfills have extremely harmful consequences for human health, plants and animals. However, an even greater problem arises in the absence of a reduce, reuse and recycle (3R) strategy. Especially for the enormous amount of textile waste that fills the aforementioned landfills, there is poor or a lack of intermediate treatment that allows for recycling and reuse. Therefore, instead of simply being disposed of in the earth's crust, it takes decades for the waste to degrade (Cvijić et al., 2021).

Research conducted in China regarding soil erosion at landfills due to the enormous amount of deposited construction waste has shown that the two main factors in risk assessment and prevention are continuous monitoring of large deformations on-site and effective risk assessment based on internal deformation data (Xu et al., 2020). The solid waste landfill is constructed to properly dispose of waste of the same category, but it also poses a risk to surrounding buildings due to landfill collapse, as well as to the health of residents (Cheng et al., 2022). Natural disasters, such as floods, generate a vast amount of waste, causing various viral diseases and potential infections that jeopardize the entire waste management system (Neuhold & Nachtnebel, 2010). Natural disasters affect every part of the globe and cannot be avoided, but it is possible to educate all target groups on how to behave before, during and after such hazards (Bryant, 2004).

Circular economy contributes to waste reduction and reuse, with a special emphasis on green practices in human resource management, which contributes to the improvement of environmental performance metrics (Shah et al., 2024).

Studies have shown that the performance improvements of green development depend on human resources and their continuous contribution to the work environment and surroundings, i.e., green training, green development and management of green resources, green awards, etc. In this way, an excellent foundation is created for the continuous improvement of the green economy, as well as raising awareness among the population to a higher level, with a special emphasis on the role and importance of municipal waste and its potential negative consequences for the environment (Lewicka et al., 2024). A special aspect of the green economy consists of three key elements: economic, sociological and ecological, which together create a new value that enhances the environment and all stakeholders living within it (Alzubi & Kontor, 2024). Recent studies have shown that human resources combined with machinery contribute to improving the business system and creating prerequisites for a stable business environment, which is a factor in the competitiveness of the national economy. Therefore, human resources represent an indispensable element of competitive advantage for the observed enterprise as well as society as a whole, because investing in intangible assets establishes the foundation for the business success of the enterprise, the economy and the system itself. In times of global crises, everything starts and ends with human resources. The ecological and economic aspects of the observed society also depend on them. Trained human resources embody a comprehensive ideology of business success for the observed organization (Saifulina et al., 2020; Usprech & Palmert, 2023).

The solid waste management system represents an important issue in modern society, with a special emphasis on the chain that constitutes it, namely waste producers, storage methods, and all stakeholders involved (Bhada-Tata & Hoornweg, 2016). In underdeveloped and transitional countries, the amount of such waste needs to be minimized through proper disposal and the selection of optimal transport vehicles, along with transportation routes for systemic waste management (Novarlić et al., 2016). Research has shown that a huge problem arises from the enormous amounts of solid waste generated after floods. The issue is even more challenging if an uneducated and uninformed population is added. The problem arises after unpredictable floods occur, with inadequate legal regulations in place. Nothing has been done to prevent floods if they occur, nor has any consideration been given to educating residents on how to behave in crisis situations (Ogbonna & Udotong, 2021).

Earlier studies have shown that due to the increasing urbanization of cities and the uncontrolled disposal of municipal waste (in canals next to rivers, forests and all other places prohibited by law), there is contamination of surface and groundwater, as well as the entire environment, because waste is deposited mainly in non-sanitary landfills and open spaces, leading to negative consequences for the entire observed society (Ogbonna et al., 2007). On the other hand, ecosystems are destroyed, and the aesthetic appearance of cities is compromised because, after

floods, there is an increase in waste volume, which, in addition to mixed, solid and electronic waste, also contains various types of hazardous waste. This poses an additional red alert and health risk to citizens' lives (Imam et al., 2008). Floods cause significant and enormous problems, especially concerning the amount of all types of waste generated afterward (waste from industry, households, etc.).

3. Municipal Waste Management: Current State and Perspectives

CWM represents a complex and demanding system. However, it can be perceived as a living entity, governed by rules that constantly evolve and require adaptation, with the ultimate goal of being a healthy environment for all living beings. As mentioned earlier, developing countries face limited financial resources for systemic waste management, which includes the construction of utility infrastructure, the procurement of municipal equipment and similar, all of which impose limitations on CWM.

The positive practice of developed countries teaches their residents to behave responsibly towards their environment and to respect their citizens, both the elderly and the youngest age groups. In these countries, waste management is taught from a very young age, starting from pre-school institutions all the way through schools and universities, making it impossible to imagine a waste management system that does not function as mandated by law. Therefore, by sorting waste at home and placing it into containers designated for specific types of waste known as valuable secondary raw materials, such as plastic and polyethylene terephthalate (PET) packaging, paper and cardboard, glass, metal, etc., the burden on landfills is reduced (in developed countries, useful waste is incinerated in incinerators), and waste is reused while creating new utility value, which emphasizes the importance of the circular economy.

Transitional countries, such as BiH, still face issues with a lack of sanitary landfills and equipment for manual and mechanical waste separation. As a result, most unsorted waste ends up in landfills without intermediate treatment and is simply disposed of. Unfortunately, the lack of financial resources and international grants contributes to an increasingly challenging situation for maintaining a healthy environment. Moreover, citizens themselves lack motivation to comply with waste management laws because there is no material satisfaction (financial incentive) for them to follow the system established by the local community regarding municipal waste disposal (separation at home and disposal into containers designated for specific types of waste).

Living culture is a response to the behavior of a specific, or observed, population. This actually means that if a waste management system is not inherent in the genes of a population, it is difficult for them to adapt quickly to countries where it is a tradition. This is one of the responses to the problem in the previous paragraph. The following question arises: As for a person living and working in the country of BiH, who is accustomed to enjoying life and using available resources without limits, even when these resources are not needed at the moment, can he change quickly and use only what is necessary or urgently needed in a given situation?

Therefore, it is simple to answer the previous question with a negative. However, people should start learning today to accept changes, especially some of them who live in the city of Doboj, whose infrastructure was completely devastated during the catastrophic floods of 2014. Despite this, a prevalent attitude persists where nature is treated with disregard, as if the laws governing it are irrelevant. There must be an emphasis on respecting neighbors and behaving responsibly towards the environment, which is a shared resource. Therefore, everything that is not necessary at the given moment but relates to limited resources for living should be used in a limited manner (e.g., drinking water, electricity and heat energy, food and similar). Developed countries may be able to withstand all natural disasters and recover quickly, but developing countries do not have the luxury until they catch up with them in terms of innovations and information and communication technologies. In addition, if developing countries want to be competitive and not use outdated equipment, they must adopt prudent and sustainable practices akin to those of a responsible steward.

Figure 1 provides a concise overview of CWM in the city of Doboj, including the stakeholders directly involved. The following section focuses more on all stakeholders and their impact on the functioning of the waste management system. It is important to note that BiH is a country with two entities and three constituent peoples, lacking unified legal regulations regarding waste management (laws applicable to one entity do not apply to the other, and vice versa). Therefore, it is a special challenge to construct a modern system and adhere to international directives on this issue.

The greatest problem faced by transitional countries, including BiH, is a lack of financial resources and limited access to international grants and donor funds. Each local community has defined rules regarding waste management, shaped by previously established policies applicable to both citizens and the economy in general. Municipal equipment is expensive, and the resources generated after primary waste treatment are limited. Therefore, it is significantly challenging to develop CWM in the city of Doboj and throughout BiH.

A major problem lies in rural areas and the irresponsible disposal of waste by the residents of those areas, either along highways, in forests, rivers, or even more dangerously, by open burning of waste. There is limited influence from inspection authorities, both in terms of personnel and potential penalties for irresponsible behavior. Only 20% of rural areas are covered by waste collection services, with extremely low cooperation. In addition, there has been

an increase in illegal landfills and potential environmental pollution.

The regional landfill is not sanitary. It is still in its construction phase and lacks shredders and similar machines that would reduce the amount of useful waste (metal, wood, plastic, etc.) after treatment and disposal.

The primary issue, which requires immediate and maximum attention, is to raise public awareness and adhere to the 3R strategy. This should be thought about today to benefit the descendants. Although there is land available for waste disposal, the waste has not undergone treatment, which pollutes the environment and poses a serious long-term risk to the entire local community.

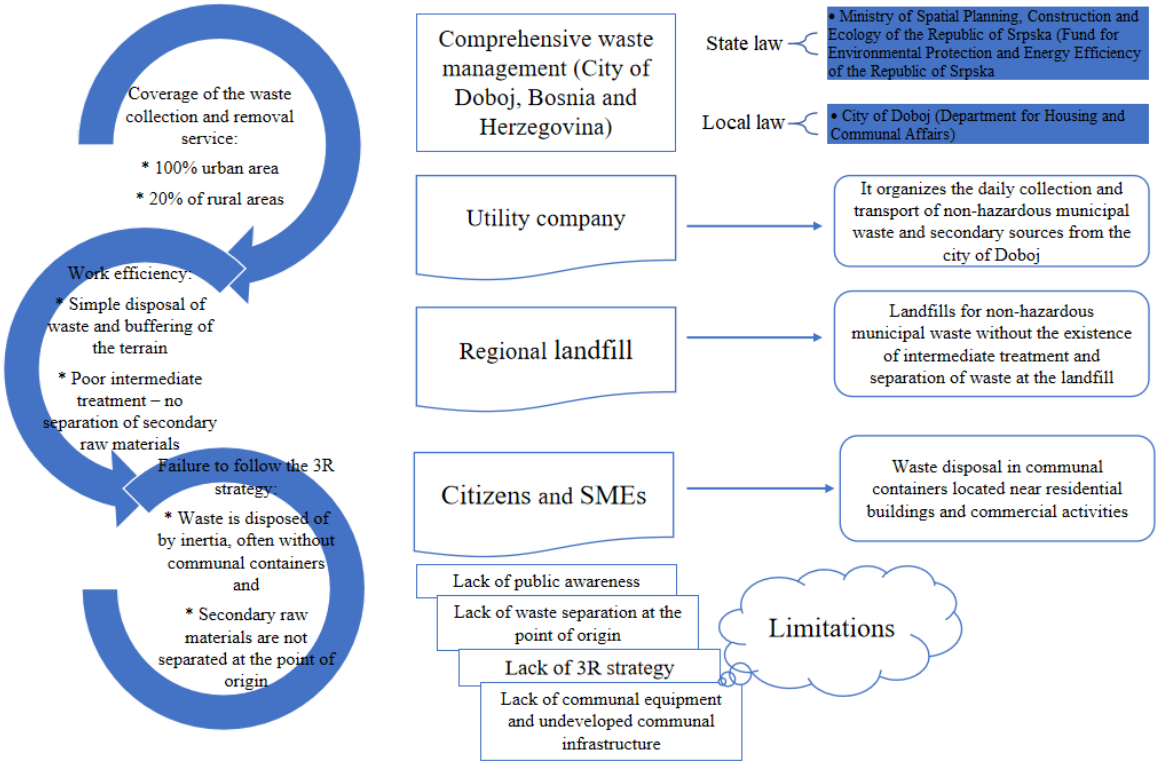

Figure 1. A brief overview of CWM in Doboj with limitations
Note: This figure was prepared by the authors.

3.1 Limitations in systemic waste collection

All utility companies in BiH "struggle" with maintaining current liquidity, such as employee salaries, obligations to suppliers and loans, procurement of new utility infrastructure, fleet renewal, etc., which consequently leads to limitations in the investment cycle related to the procurement of modern and competitive equipment and tools for daily operations. The vehicles for collecting and transporting waste are 10 to 20 years old, which is outdated. However, the current financial resources are largely sufficient to cover current expenses, leaving little room for potential crisis situations such as natural disasters. Table 1 presents the current limitations evident in the entire BiH, which reduce the efficiency of systemic waste management.

Therefore, a major problem in BiH is primarily the lack of public awareness, proper separation, collection and ultimately recycling of useful waste (secondary raw materials). There is no material satisfaction (for the population, as the largest waste producers) for properly separated secondary raw materials, which are further handed over to recycling centers where new value is created, aiding the circular economy.

In the Republic of Srpska in 2020, 400,000 tons of municipal waste were produced, which is an average of 0.95 kg per person. Approximately 40% of this waste was organic, while another 40% was packaging waste (paper and cardboard, foil of above 50 microns, glass, metal, plastic and PET). Unfortunately, only about 5% of this total waste is recycled (due to inadequate strategy and a systemic waste management approach), with a reserved opinion, as approximately 30% of the population is still not covered by waste collection services (Vlada Republike Srpske, 2024). Therefore, there is potential when it comes to secondary raw materials and the creation of new value from waste. However, on the other hand, there is a lack of adequate support from local communities and the state. Aiming to join the EU, BiH has taken some steps to define systemic waste management at the level of the entire country. Unfortunately, no strong determination leaves the country stagnant.

Similarly, the pressing issues and primary limitations in CWM in BiH are the non-standardized containers for waste disposal, their insufficient number, and an inadequate strategy for creating municipal collection routes when

defining waste collection and transport services, which result in multiple transport intersections, idling and inefficiencies in waste collection and increased fuel consumption.

The following questions arise: What are the capacities of BiH and local utility companies if they face natural hazards such as floods and earthquakes? How to cope with nature that constantly warns people and gives them signals to change the approach to dealing with it, with a special emphasis on uncontrolled waste disposal? Is BiH technically operational during and after the period of natural hazards?

The next section provides most of the answers by reviewing relevant situations during the catastrophic floods in May 2014 in the city of Doboj, which were directly the result (one of the causes) of uncontrolled waste disposal. This led to the creation of so-called water plugs and flooding of the inner city core. It is underlined again as a result of human factors. Similar scenarios exist in other developing countries as well as in wealthier global economies.

Table 1. Limitations in systemic waste management

Issue	Cause	Consequence
Waste collection is conducted collectively by one vehicle, without treatment.	• Lack of standardized municipal containers; • Lack of public awareness.	• Useful secondary raw materials end up in landfills without creating new value; • Direct environmental pollution and human health hazards.
A source of financing for utility companies	• Directly from end-users without assistance from the local community or state aid.	• Lack of financial resources to cover operational costs and for new investments (financial inflows are insufficient for the normal functioning of systemic waste management).
Vehicle fleet	• Lack of financial resources for purchasing modern (economical) vehicles (Euro 6 engines and hybrids).	• Rising operating costs (investment in old vehicles, which are 20 years or older) lead to enormous fuel and lubricant consumption, as well as high costs for truck servicing and repairs.
Inspection supervision and control	• No systemic and continuous actions regarding offenders and illegal disposers of municipal and other types of waste.	• Illegal landfills • Environmental pollution directly affects clean air, water and habitats in general for plants, animals and humans.
Reporting system on the collected amounts of solid waste compared to other waste categories	• Lack of continuity on this issue (availability of information varies from one local community to another).	• Restricted access to foreign donations in this area, grants and state aid (entity-level).
Informing citizens and providing education in the field of waste management	• Insufficient interest from the local community and key stakeholders. • Insufficient education on collection and, before that, separation and final treatment of useful waste (useful secondary raw materials from waste).	• Environmental pollution directly affects clean air, water and habitats in general for plants, animals and humans. • Potential viruses resulting from uncontrolled waste disposal directly affect the health of residents.
Tradition and behavior of all individuals in the domain of waste collection and disposal	• Irrational use of natural resources.	• Production of enormous amounts of waste directly contributes to the creation of illegal landfills and potential disasters.

Note: This table was prepared by the authors.

4. Crisis Situations of Floods

Floods, as a natural hazard, are not so dangerous nor are they a threat to the observed population or material resources if acted upon preventively in a systemic and planned manner. A written strategy and its proper implementation are the primary steps in building a positive business environment. This implies the inclusion of all interest groups, from the population to the economy, as well as leaders and legislative and executive authorities.

In the "blood" of the inhabitants of the Balkans is the tendency to view every potential disaster, natural or otherwise, optimistically and under the principle that "it won't happen to me." However, globalization and global changes have led to increasingly turbulent fluctuations, especially concerning climate change. In BiH, distinct seasonal transitions have become blurred, with winters now being almost non-existent or very brief, while summers are increasingly hot and problematic.

Therefore, the first and fundamental step is prevention, i.e., preventive actions and education (primary, secondary and higher education) of all participants in the system of primary waste sorting, separation, and disposal, aiming to prevent the emergence of all potential illegal landfills, which would be a long-term problem in case of

a potential natural disaster. Increased allocations from the state budget for these purposes, alongside an aggressive campaign on preventive actions and the dangers posed by natural hazards, are essential.

Modern municipal equipment and tools, alongside modern municipal vehicles and machines, such as so-called loaders and combined machines, represent the basis of all local communities in BiH and their respective departments. A particular aspect of financing, both by the state and through the planning of specific budgets for local communities, relates to strengthening the resilience of each local community individually, that is, enhancing the resilience of the local community and thus the population to natural disasters and other emergencies. By "instilling" behavioral rules among the population during crises and natural disasters, cooperation at all levels can increase, ultimately leading to greater efficiency, effectiveness and resilience of the entire system.

The process of emergency management involves phases of prevention, readiness, action and recovery after the impact of the emergency has passed. The system's functioning depends precisely on the preparedness and readiness of all participants in the chain affected by an emergency (Cvetković, 2018). Figure 2 shows a proposal for managing emergency situations with a focus on SWM.

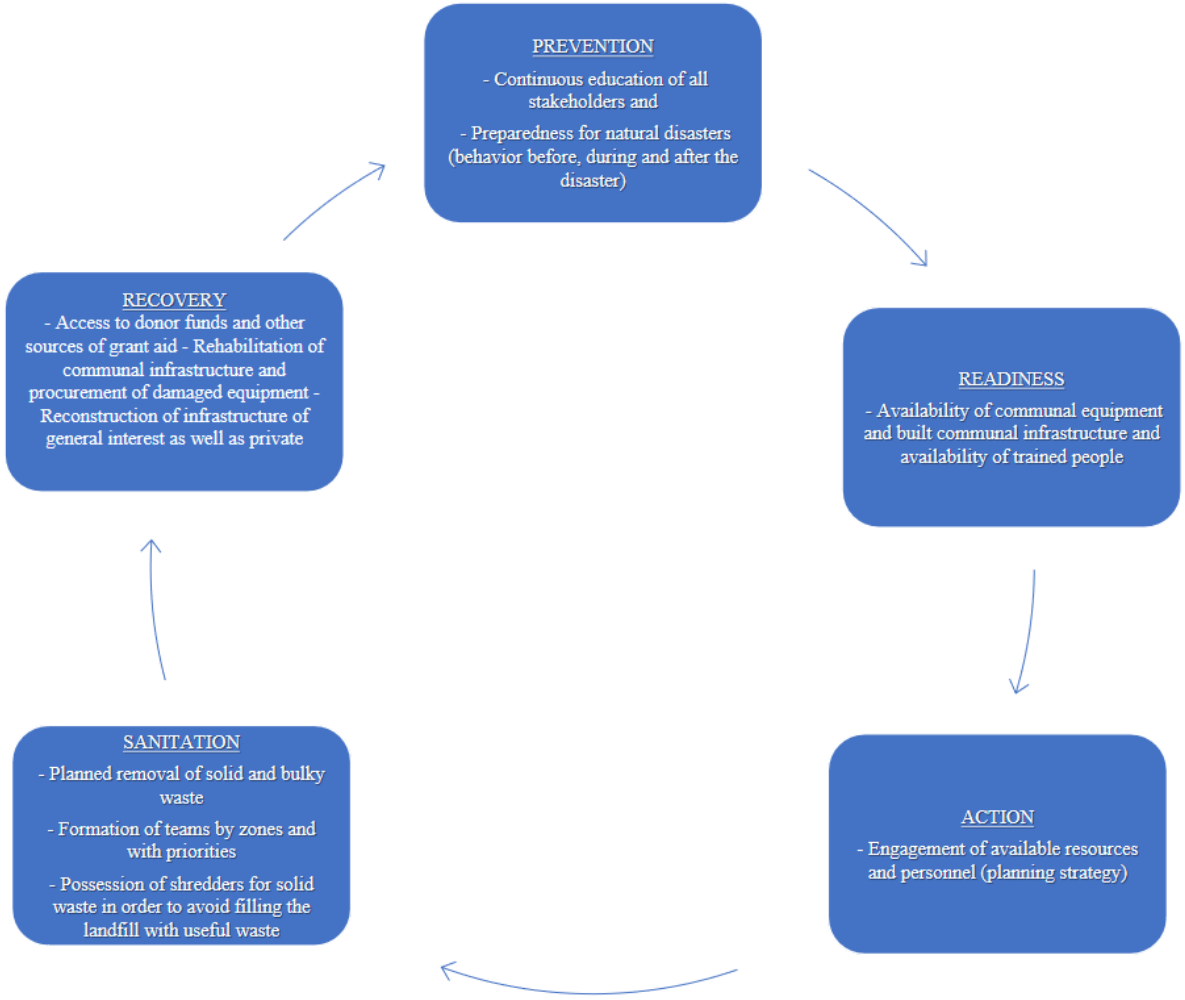

Figure 2. Proposal for managing emergency situations by focusing on SWM
Note: This figure was prepared by the authors.

The proposal to improve the waste management system during natural and other disasters starts with prevention. This is reflected through the establishment of clear legal regulations, which serve as the basis for all subsequent steps in the chain of the proposal for the improvement of the entire system. Possessing municipal equipment and tools for work during and after emergencies is also a crucial factor that can mitigate overall material damage caused by the action of these negative, natural hazards. Additionally, it is important to have trained and available workers on the front lines to combat potential floods, including material resources. It is important to make a plan and stick to it as a strategic option because it not only resolves potential problems but also conserves already scarce financial and material resources. With international and foreign donors, as well as solidarity from local communities in BiH, issues such as damaged utility infrastructure and other infrastructure of general public interest are addressed. Additionally, using the funnel method, problems faced by the population of affected areas, such as the threat to

their material property, are also resolved. Within the limits of available financial resources, the economy is rehabilitated, including micro, small, medium and large enterprises, respectively.

4.1 A Theoretical Model of CWM in Crisis Situations

In conditions of unstable business and a natural environment, legal principles that apply under normal circumstances are not applicable when changes are caused by natural or artificial means. It has been emphasized several times in this study that natural hazards are becoming more frequent, affecting the entire globe suddenly and often without a specific warning. However, this is often not entirely sudden, but rather the accumulation result, largely due to human factors that contribute to disrupting natural balance and jeopardizing their own existence. Nothing happens suddenly and overnight; it is the result of the negative influence of humans on the environment.

The negative impact of CWM on human health and the environment was examined in this study. Therefore, natural hazards are used to study broader issues directly related to human well-being and material possessions, with a focus on waste management in crisis situations and its actions before, during and after floods.

One of the authors of this study is from the city of Doboj, which is one of the 10 largest cities in BiH, and works in a waste management position at a local utility company. According to him, after catastrophic floods in just a few days in May 2014, the amount of solid waste equivalent to the average for 10 years under normal conditions was transported to the local landfill. Through the quick actions of the local community and the involvement of the government and key target groups (business owners with heavy machinery, experts and others), all the waste at the landfill was disposed of (unfortunately without treatment) to prevent the spread of viruses and potential contamination. After being rebuilt, the city looks more beautiful and modern ten years after the disaster, benefiting all citizens and the wider community.

Figure 3 presents a theoretical model of CWM with a specific emphasis on crisis situations and emergencies. It indicates guidelines for behavior before, during and after emergencies, with a focus on the waste management segment.

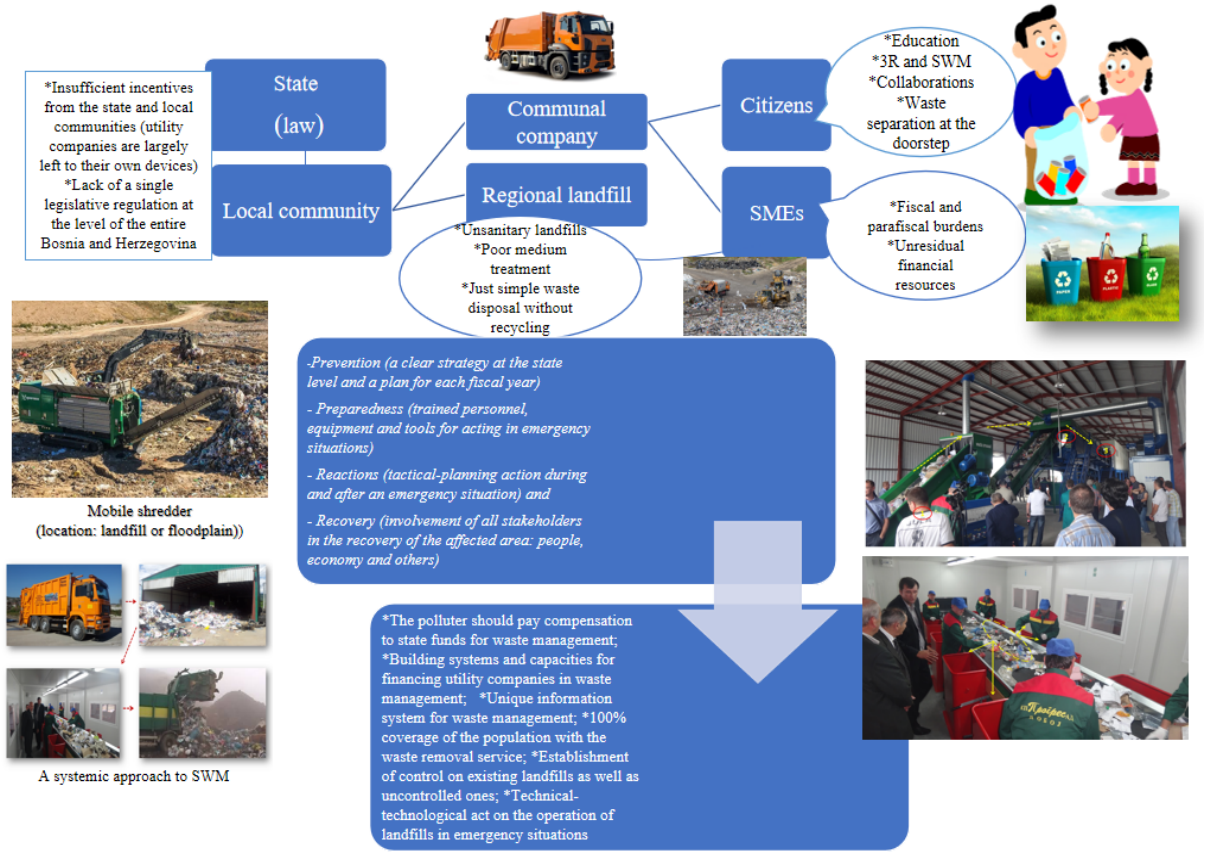

Figure 3. Theoretical model of CWM with a special emphasis on emergency situations
Note: This figure was prepared by the authors.

From the mentioned model, a series of proposals and recommendations can be drawn for the next period, aiming towards long-term goals (next 20-50 years) while adhering to guidelines and legal regulations in the field of waste management. A series of recommendations are presented below for local communities in BiH, which should be

followed in the domain of waste management and crisis situations (natural hazards) to avoid being unprepared in case of floods caused by short but intense rains in parts of certain settlements or entire local communities. The prevention and readiness of these aforementioned stakeholders play a crucial role in addressing these issues both in the short and long term. Thus, municipal waste and natural hazards are the focus of this study, accompanied by specific recommendations to relevant institutions on how to anticipate and ultimately mitigate these hazards if they occur.

Suggestions for improving the systemic approach to emergency situations in the field of waste management are as follows:

- A memorandum of cooperation among local communities throughout BiH should be established, aimed at providing unified legal regulations in the field of waste management at the level of the entire BiH. Furthermore, it should ensure that material and technical resources are available for key stakeholders directly involved in this sector, with compensation mechanisms in place, such as state co-financing for part or all of the fees for services provided;
- Each local community should have an active service (department) of civil protection, responsible for conducting outdoor exercises periodically, such as simulations of crisis situations (flash floods in a short period, landslides, disposal of solid and bulky waste in hard-to-reach areas, direct cooperation with all citizens and businesses), and continuously applying for non-repayable funds from domestic and international donors;
- Equipment (small and heavy machinery, as well as other essential resources) to be utilized in crisis situations should be procured. During the catastrophic flood in the city of Doboj in 2014, there was a lack of heavy machinery for managing solid and bulky waste. These so-called municipal shredders were urgently needed to further sort and utilize all secondary raw materials from the existing flood waste. After recycling, the funds obtained from it can be invested in the procurement of new and essential municipal equipment (such as municipal vehicles, containers, composters and so on). Therefore, each local community needs up to three mobile shredders (one installed at a landfill, one in an urban area and one in a rural area) to be used for cleaning flood waste in emergencies, as well as regularly for waste that ends up at the landfill without intermediate treatment (such as old mattresses, sofas and other household furniture, old tires and vehicles designated for disposal, old electrical waste, etc.). This aims to create new utility value instead of simply burying waste at the landfill, i.e., extracting all useful resources from the waste (metals, wood, plastic and everything else that can be recycled and reused to create new utility value);
- Citizens should be continuously educated on how to behave in natural disasters (prevention and actions during and after a crisis situation), with a special emphasis on CWM (separation of waste at home and disposal in specifically designated containers according to types of municipal and useful waste, aiming to avoid the creation of illegal landfills and environmental pollution). By establishing a clear systemic approach to the identified need, a clear waste management strategy applicable to the entire country can be created to prevent damage affecting human and material factors in the event of a severe or short-term natural disaster. Frequent and intense rains can lead to torrential streams and river overflows. If drains are not cleaned and various types of waste are exposed to these elements, it poses a threat to public health, i.e., waste becomes a significant risk to both nature and the population in general.
- In crisis situations, it is necessary to establish an optimal transportation route that serves as a practical model for disposing of non-hazardous municipal waste and to engage specialized services for disposing of hazardous waste and dangerous substances. Therefore, starting from the main focal point affected by water hazards, the inverted funnel method can be used to collect, treat and dispose of municipal waste in other less affected areas compared to those most severely impacted by floods and similar hazards. Waste is collected starting from the nearest point and moving towards each subsequent (closest) point using a mobile shredder. It is necessary to approach the treatment of solid and bulky waste by transporting it to a regional landfill with additional treatment before final disposal, adhering to the principles of the 3R and natural laws. Only in this way can the lifespan of the landfill be extended, thereby protecting human health from potential viruses.
- Quarterly outdoor exercises related to emergency response should be conducted by relevant departments and rescue personnel during hazardous moments, with the opportunity for the interested public to observe and learn from practical examples to make preparations for potential natural disasters.
- An annual budget should be defined specifically for crisis situations, directly linked to the renewal of existing equipment and the purchase of modern and innovative solutions. New natural phenomena are in effect, i.e., globalization and global changes have led to changes in nature, leading to frequent disasters accompanied by "unusual" weather conditions and events.
- All open city landfills should be converted into sanitary landfills, and those that do not meet these conditions must be urgently closed because they only "help" even more adverse weather conditions and events (waste is scattered in landfills due to rain and strong wind, leading to terrain erosion endangering people in homes located near the landfill).

5. Conclusions

Municipal waste management occupies a low-accumulative sector of the economy, characterised by small revenues from services provided, yet it carries significant responsibility regarding the environmental and human health consequences on a large scale, if approached in an unplanned, unsystematic manner or in opposition to biodiversity and nature in general.

Countries in transition, as well as poor countries observed globally, face a significant issue related to development transformation and keeping pace with the technical and technological advancements of developed countries. A major problem is outdated municipal equipment and trucks that are 20 years old or more. This issue raises a pressing concern: the efficiency of modern and contemporary systemic waste management. Vehicles in these countries are still at Euro 3 and Euro 4 engine levels, whereas developed countries utilize modern Euro 6, hybrid and electric vehicles.

Regarding natural hazards and climate change, there is a constant adaptation to a new approach to CWM. However, the residents of the observed area and their resistance to changes as well as a lack of education could lead to potential problems in the event of crises (natural hazards). There is a lack of public awareness regarding the handling of municipal waste and the potential issues arising from it. In the event of natural disasters, such as floods, there is uncertainty about how to manage waste to prevent viruses and diseases among people. Amid intense rains that persisted for days in BiH and caused widespread flooding and significant material losses in May 2014, one of the greatest challenges, besides the lack of awareness among the population, was the issue of managing all types of waste (flood waste from households and businesses, and all other waste generated by the uncontrolled and rampant flooding of the Bosna River). Unfortunately, this phenomenon was not adequately predicted in the city of Doboj or globally. However, this study provides specific proposals for the behavior of people and the entire observed community during crisis situations, both from a legal perspective and from a material standpoint (procurement of necessary municipal equipment, construction of utility infrastructure and similar measures).

Theoretical-practical recommendations given in the theoretical model of this study point to the urgent action of all local, regional and state stakeholders, aiming to build a positive environment and engage in preventive measures in emergency and crisis situations. Without support from the state and local community, a utility company in the observed city or any municipality in BiH has little chance of success in dealing with natural hazards. Therefore, the lack of financial resources and donor funds complicates the creation of a CWM strategy in crisis situations, as does the inadequate coordination among all local communities in the chain, which should provide all material and human resources to affected areas during natural disasters.

Heavy municipal machinery (mobile shredders) and a systemic approach to the 3R strategy, along with an educated population on handling municipal and flood waste, represent the future vision of successful waste management policy in BiH, even when facing short-term natural phenomena caused by global changes (such as flash floods, torrential streams and the like).

Collaboration among all levels of government in BiH, especially utility and related companies, along with quarterly and periodic rescue exercises in emergencies, will contribute to a positive response of the entire system in the long term.

Is BiH affected by global changes and located in seismic and flood-prone areas, geographically observed? Will future generations achieve stronger synergy in the fields of systemic action and CWM? Are local communities financially and materially sustainable enough to confront potential natural hazards? These are just some of the future research proposals on this exceptionally sensitive yet scientifically important and interesting topic.

Data Availability

The data used to support the research findings are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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