*Review*

# The Implications and Effects of Medical Waste on Development of Sustainable Society—A Brief Review of the Literature

**Costel Bucătaru [1], Dan Săvescu [1], Angela Repanovici [1,*], Larisa Blaga [1], Ecaterina Coman [2] and Maria-Elena Cocuz [3,***

[1] Department of Product design, Faculty of Mechatronics and Environment, Transilvania University of Brasov, 50003 Brașov, Romania; costel.bucataru@unitbv.ro (C.B.); dsavescu@unitbv.ro (D.S.); larisa.blaga@unitbv.ro (L.B.)
[2] Department of Management and Economic Informatics, Faculty of Economical Science, Transilvania University of Brasov, 50003 Brașov, Romania; ecaterina.grajdieru@unitbv.ro
[3] Fundamental Prophylactic and Clinical Disciplines Department, Faculty of Medicine, Transilvania University of Brasov, 50003 Brașov, Romania
* Correspondence: arepanovici@unitbv.ro (A.R.); maria.cocuz@unitbv.ro (M.-E.C.)

**Abstract:** The sustainable development of humanity imposes precise norms regarding the management of natural resources, their extraction, use, and the introduction in a complex, innovative circuit of the waste resulting from exploitation. The paper deals with some aspects related to the sustainable management of general medical waste on the one hand and the medical waste specific to the COVID-19 pandemic, on the other hand. Medical waste requires special treatment given its impact on the environment and on humanity. The management of activities related to its storage, transport, destruction is an important point in the sustainable development of mankind, especially in the current context of the pandemic. Medical waste is in a continuous increase in quantity and involves many effects in various activity fields. Through a scientometric study in the Web of Science—WOS database, the authors identify clusters of keywords, analyze the articles identified in the WOS and identify the main research directions and existing concepts. Corroborating and interpreting the results obtained, three significant trends of approach to medical waste are identified: M—management (1); E—exposure (2); and D—distribution (3). An extensive map of the concepts is made, a narrow map of the concepts used, and a theoretical map of the concepts. The link between medical waste and the development of a sustainable society is demonstrated, and it is possible to open new research directions. The scientometric research undertaken on 1192 WOS articles that were published in 2020 led to the selection of 32, focused on issues related to hazardous medical waste, especially of COVID-19 patients. Following this approach, the authors were able to see, by comparison, the different forms of management of this waste in different countries, thus being able to contribute to the creation of procedures for the collection, storage, and destruction of this hazardous waste, with direct influence on the environment.

**Keywords:** sustainability; medical waste; higher education institutions; impact; economic aspects

## 1. Introduction

COVID-19: What is to be done now? This pandemic has affected all areas of activity. The most devastating effects were on health, the environment, and education. Medical waste has exploded in terms of quantity and influenced the reorganization of their management in hospitals, the public domain, and the environmental approach.

Waste remains a complicated issue for human society due to its health and environmental, economic, and social impacts. In particular, medical waste negatively influences the health of the population and the environment, so it must be managed with great care.

The influence of hazardous medical waste on society and the environment, as a result of previous research, leads to a question: What is more critical in the issue of

medical waste? Management—by creating and implementing sorting procedures, expenses/bed/patient/day, material and staff costs, especially that in these times of pandemic the need for staff has increased considerably; Exposure—by creating specific procedures related to the transport of waste from hospitals to collection/incineration points, expenses related to equipment, personnel, fuel, maintenance; Distribution—procedures regarding a superior recovery of medical waste, the possibility of using combustion residues, so as not to affect at any time the quality of the environment.

This study aims to probe the literature by scientometric methods, the content of the literature published in the Web of Science—WOS database, the influence of COVID-19 on the approach to medical waste and environmental sustainability, and their influence on society. The scientometric analysis made possible the highlighting of the study deficit on this topic, the empirical studies were analyzed, and the needs and effects on the scientific elements to be developed were highlighted, the need to promote the results through teaching/education.

The purpose of the article is to find the strong points resulting from the analysis of the literature on medical waste from the beginning of the COVID-19 pandemic and to see in which direction most research is heading related to the sustainable management of hazardous medical waste. Also, this study gives a general image of waste management in different countries, and contributes to creating specific procedures in the way to optimize collection, transport, storage, destruction/incineration, useful in Romania, but also to disseminate this experience to other countries.

This paper is divided into the following sections, which have been considered key to achieving the proposed objectives. Section 1 is the introduction; Section 2 defines the research method, research questions, and results analysis. Following the scientometric analysis, 32 articles have been selected that deal with the urgent and exciting research directions during COVID-19. Three significant research directions in medical waste were identified, M—Management, E—Exposure, D—Distribution. Section 3 presents discussions on the three approaches, M, E, D. Section 4 develops the paper's development conclusions.

## 2. Research Method

### 2.1. Literature Review by Scientometric Methods

A scientometric study was performed. The research was conducted on the Web of Science database. Articles on the subject of Medical Waste were searched. The 2020 papers were included in the study. We imposed this limitation to analyze the literature that appeared during the COVID-19 pandemic.

The database, downloaded from the Web of Science, was analyzed using the VOS Viewer software (VOSviewer version 1.6.16, free software from https://www.vosviewer.com/ (accessed on 11 January 2021)).

We limited the options to analyze the authors' terms in the whole article and the articles' abstracts. VOS viewer software allowed us to view the map of these concepts and divide these terms into clusters. We analyzed these clusters and determined the research directions for this field during COVID-19.

The following three research questions were defined:

RQ1: What are the most critical research directions addressed in the articles on medical waste?

RQ2: What is the impact of medical waste on a sustainable society with the advent of COVID-19?

RQ3: How is the impact of medical waste assessed?

### 2.2. Stages of the Scientometric Study

The realization of the scientometric study included seven stages according to Table 1, starting from the formulation of the problem to the establishment of protocols and research criteria, data extraction, which were subsequently analyzed, synthesized, and discussed.

**Table 1.** Scientometric study's stages.

| No. | Stages | Description |
|---|---|---|
| 1 | Problem Formulation | Mapping and bibliometric analysis of publications using descriptors |
| 2 | Research Protocol | "Medical waste" |
| 3 | Research Database | Claryvate analytics, WEB OF SCIENCE—WOS 7/09/2020 |
| 4 | Eligibility Criteria | Refined by: STRING 1: publication years: (2020) and web of science categories: ("medical waste") As results: 5112 articles Refined by: STRING 2: publication years: (2020) and web of science categories: (environmental science) and web of science categories: (public environmental occupation health) and (engineering environmental) and document types: (article or proceedings paper) As results: 1265 articles |
| 5 | Data Extraction | Bitext format |
| 6 | Analysis And Synthesis Of Results | Qualitative (descriptive) and quantitative (bibliometrics) using VOS Viewer |
| 7 | Discussion Of Results | Exhaustive analysis and verification of data obtained |

In the research stage, which consisted of STRING 1, which included all the requirements/criteria established as necessary for the study, it resulted in 5112 articles, then STRING 2, which resulted in 1265 items. This methodological procedure is represented in Figure 1.
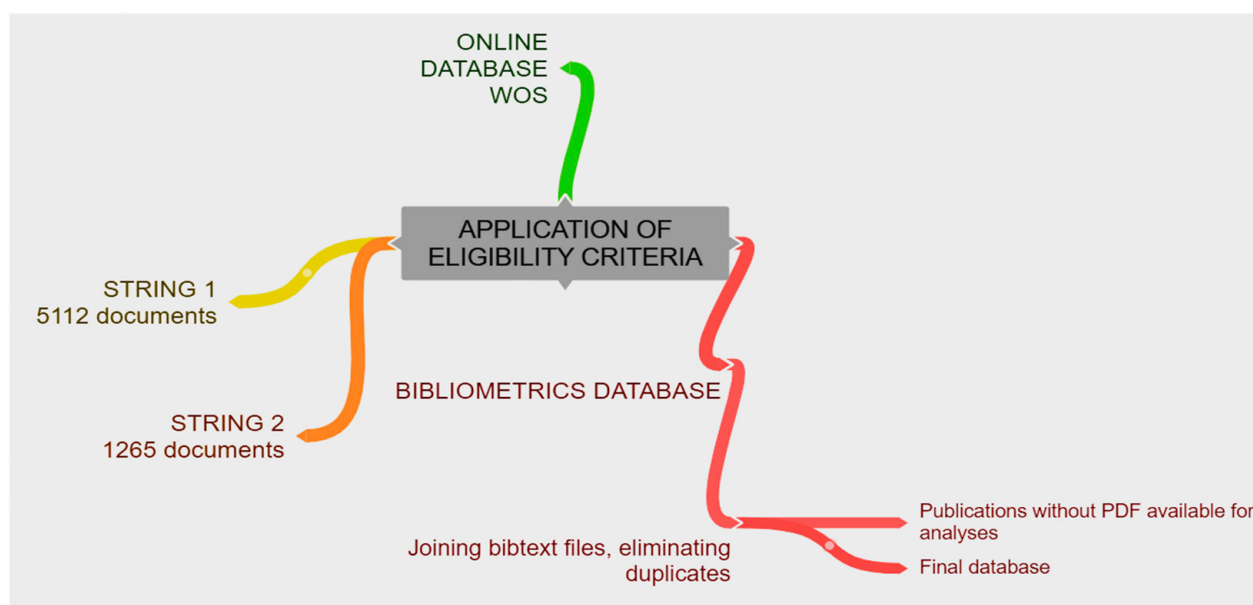


**Figure 1.** Research methodology scheme.

Using VOS Viewer, the database was analyzed in STRING 2.

VOS Viewer is software used for bibliometric analysis using databases extracted from WOS.

We limited the research to descriptors that appear in the database at least three times. Of the 4818 terms, 371 met the threshold. For each of the 371 words, VOS Viewer calculated a relevance score, and 60% of the most relevant terms were selected.

Analysis of the descriptors used in the title and summary was performed (Figure 2). We obtained three clusters of descriptors.
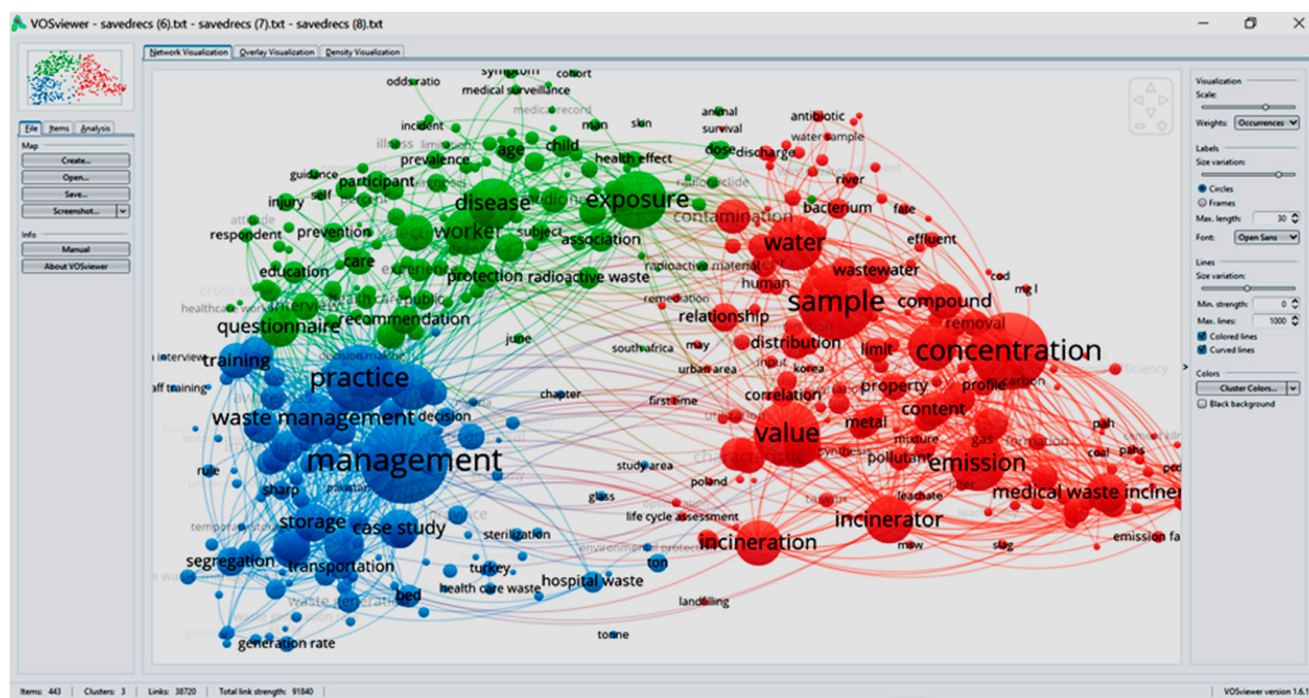


**Figure 2.** Generating clusters in "waste management" research using VOS Viewer.

The concepts map resulting from STRING 2 is presented in Figure 3.



**Figure 3.** Concept's map resulted from STRING 2.

*2.3. Results Analyses*

Three research directions were identified in the studies undertaken related to Medical Waste (MW): Management—M, Exposure—E, Distribution—D.

These were extracted from the analyzed articles, downloaded from the database, and classified in three directions. Since the onset of the pandemic and a significant increase in MW, there has been a growing interest in the MW approach.

Figure 4 summarizes the identified items in STRING 2, limited to items dealing with MW in the three directions. There are 32 items.

The authors analyzed the content of the 32 articles in the three directions: M, E, and D.
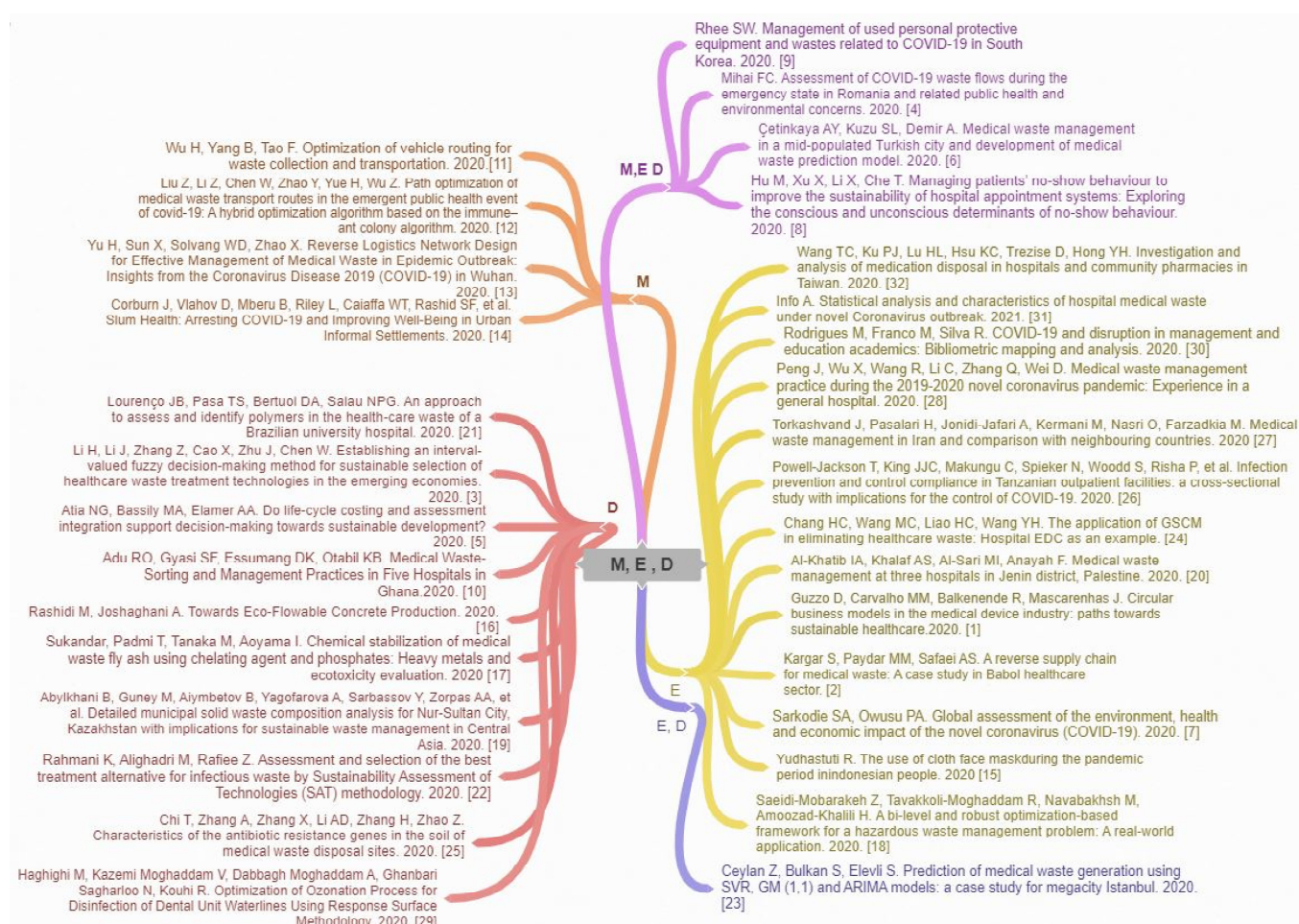
**Figure 4.** Content analysis taking into account authors and type of study [1–31].

### 2.3.1. M—Management

The management of COVID-19 in Romania, in a state of emergency, between 16 March and 14 May 2020, imposed a national blockade with restrictive measures and social distancing, with a tremendously strict restriction on population mobility, only justified and minimal travel and having only activities reduced economic, and the population entering technological unemployment [4]. A rapid assessment method of potentially infectious waste flow, the importance of medical and municipal waste management systems, and services in combating the COVID-19 virus in the community was necessary [4].

Cetinkaya et al. [6] present general data, statistics concerning medical waste per daybed in the USA, UK, France, Turkey, and a fair comparison with data from Chapter 18 of the Europe Union Catalogue. In conformity with the Medical Waste Control Legislation, the wastes from healthcare units are classified into six categories: general wastes, infectious wastes, genotoxic waste, pathological wastes, sharps waste, and hazardous wastes. According to this classification, the authors created a model for waste management.

Since the first appearance of the virus in the Wuhan food market in December 2020, appearing in the form of "pneumonia with unknown etiology", on 11 March, it was declared a universal pandemic and treated as such, making a comparison with SARS (2002–2003), Avian flu (2003–2009), or Ebola (2014–2016). Sarkodie et al. [7] analyze the impact of COVID-19 on humanity under different aspects: economic, environmental, and social impact, expressing opinions on policies worthy of consideration, monetary and health policies necessary to improve the living conditions of the population.

In this paper [8], Hu M et al. establish a model to optimize the flow of patients to hospitals to reduce waiting time and especially the discomfort created by the accuracy of

the patient scheduling process. Hypotheses to be considered from a multistage perspective were tested. Lack or delay in scheduling medical examinations is dependent on: waiting time, days or weeks, age, the language of conversation, living environment (urban, rural), schooling level, etc.

Liu and Li [3] establish an algorithm useful to optimize urban waste storage sites. They use an ant colony–tabu hybrid algorithm, taking into account the actual situation of COVID-19, for a fair and real analysis of environmental impact.

Also, the authors made a selection of temporary storage stations and realistic transportation demands. Using their algorithm, an efficient transport model of medical waste between hospitals and temporary storage stations can be created.

A multi-objective program, realized by Hao [13], is established for a longer time period, for a fixed number of data entries. This program is based on the medical waste transport network, and as a result, determining the best temporary storage locations and transport strategies. It is known that in a brief period, in this COVID-19 time, medical waste has exponentially grown, which needs measures for efficient management [13].

Any critical health situation creates economic, social, and environmental problems. Jason Corburn et al. [14] analyzes the way to improve and protect people, to improve their lives, and well-being, for people with modest incomes, low, on the verge of existence, migrants and proposes economic, social, and psychical measures (maybe major psychic influences leading to suicide).

The study by Maria Rashidi [16] is focused on integrating expired plastic syringes into the matrix of flowable concrete mortar, looking like a fine aggregate. This can be used in other applications and is well accepted by the environment. The study aimed to determine the properties of concrete forms obtained from used plastic syringes, especially hardness and durability.

Chrisanthi Vavva et al. [32] created a procedure for the stabilization of fly ash produced by a Greek MW incinerator. In the beginning, they present a detailed characterization of the fly ash, based on the European standard leaching test EN 12457/2 (2002), and according to the results, they studied the concentration of Pb, Total Dissolved Solids (TDS), the legal limit values for pH, density, particle size dimension, conductivity, chloride, and fluoride concentration, etc.

The real problem is to estimate the amount of waste to be generated in the next years. The authors analyzed the evolution of MW (Medical Waste) in Istanbul, the biggest city in Turkey. This can be critical for the evaluation of existing waste treatment service capacities. This study was realized to evaluate the performance of various mathematical modeling methods to anticipate medical waste generation [23]. These were used to estimate annual medical waste Autoregressive Integrated Moving Average (ARIMA), Support Vector Regression (SVR), Grey Modeling (1,1), and to conduct Linear Regression (LR) analysis, in the period 2018 to 2023. All databases collected from 1995 to 2017, provided from the Istanbul Metropolitan, were utilized to examine methods' forecasting accuracy.

The problem addressed by the authors is to eliminate medical waste in order to improve the quality of the treatment process of patients and to create a support system of management named green supply chain management (GSCM). This study used a hospital's emergency department crowding (EDC) to illustrate how to establish an emergency medical service (EMS), based on the Taguchi model, creating a simulation system to obtain a concrete parameter for solving hospitals' EDC and waste problems and increasing healthcare quality [24].

The influence of incinerated waste on soil quality is the subject of Ting Chi's research [25]. Antibiotic resistance genes (ARG) were determined for 45 different soil samples containing medical waste. There were physical and chemical analyses (i.e., dry matter content, pH value, and metal content). The genomes of microorganisms from the soil were extracted for high-throughput sequencing and big data analytics.

Research by Haghighi [29] is oriented on microbial contamination in dental unit waterlines (DUWLs). There is a potential risk of infections in immunocompromised

patients and medical staff who are usually exposed to contaminated water and aerosols generated from DUWLs.

### 2.3.2. E—Exposure to Medical Waste—Risks

The sources of COVID-19 medical waste are identified: hospitalized patients, people in quarantine, people in isolation at home. There is an increase in the amount of medical waste during the emergency and alert periods caused by the COVID-19 pandemic. Deficiencies are identified in collecting waste from quarantine and isolation sites—mixing and disposal together with household waste. A COVID-19 waste monitoring model is proposed in [4].

In South Korea, face protection masks and general protective equipment (PPE) used by medical teams are classified as medical waste. Rhee et al. identified that personal protective equipment used by hospital medical staff can lead to indirect infection of other people without contact with infected patients, and also the increase in the volume of medical waste represented by the personal protective equipment used [9].

Adu et al. identified deficiencies in waste collection in hospitals—due to the lack of a unitary color coding and labeling system, they identified deficiencies in the behavior of medical waste sorting among medical staff and recommended the organization of regular training courses for health workers [10].

Yudhastuti says that the use of cloth masks as an alternative protection measure during the COVID-19 pandemic, along with other protection measures (handwashing, physical distance, avoidance of crowds) reduces the amount of medical waste [15].

The source of infection can be effectively controlled by MW management. Improper management of medical waste can increase the spread of COVID-19. Classification of medical and household waste as waste in direct causal connection with COVID-19 and their management should be carried out along with the establishment of multidisciplinary teams for infection control and MW in hospitals [28].

### 2.3.3. D—Distribution

It was proposed to study an efficient and reliable supply chain of waste from the medical industry. A multi-criteria and multi-period model with three objective functions was proposed: the first of these minimizes total costs; the second refers to the selection of scaling technology, and the latter reduces the total stored medical waste. Saeidi–Mobarakeh created a "tri-objective MILP" model. This model refers to the optimization of medical waste management [18], very relevant being the appreciation of waste treatment technologies from the medical industry in emerging economies in a sustainable way.

Alternative waste treatment technologies in the medical industry are being studied by Li H et al., including their incineration, steam sterilization, microwave or ultraviolet heating systems as well as disposal in landfills; the results indicate that the established method is useful to help prioritize waste treatment technology in the medical industry. The selection of the most sustainable waste treatment technology in the medical sector in today's economies takes place according to the decision-makers who simultaneously consider various criteria [3]. A study shows that "integrating life cycle costs and life cycle assessment through the value chain reduces costs, improves environmental performance and improves economic and environmental efficiency in strategic decision-making". It examines whether the integration of life cycle cost (LCC) and life cycle assessment (LCA) "helps decision-making in a sustainable way".

In his study, Ati presents a challenge to the public sector by exploring the rules of waste management in the medical industry. The results obtained presented the importance of the classification stages in terms of reducing processing costs. The burning of waste from the medical industry is the most common method of treatment, which influences the total costs of the system but, most importantly, the impact on the environment [5].

According to Rhee et al. medical waste management flow should follow the steps: "Disposal in the medical waste container"; "Storage in the designated installation"; "Vehicle transport for medical waste"; and "Incineration treatment" [9].

Efficient programming of one or more routes of waste collection vehicles from the medical industry would be an optimal way to reduce collection and transport costs. At the same time, once this "correct and efficient" way is applied, the negative effect of specific waste would be automatically reduced and, at the same time, we would not be unsustainable in relation to the environment [11].

A two-tier optimization model is developed by Saeidi–Mobarakeh for decision-making on the hazardous waste management framework. A strategic problem of reverse network design is considered to be the issue of waste collection as a lower level of the decision hierarchy [18]. They selected the most effective alternative to treating infectious waste resulting from the medical industry by assessing the "sustainability of technologies" (SAT). This methodology contains three essential steps, such as "screening, scope and detailed evaluation". All the information needed to obtain the data is obtained by applying a questionnaire to medical and support staff; this questionnaire is based on questions about the rate of waste generation, active beds, average waste, waste management, treatment of infectious diseases, and a field visit. Depending on certain factors, each aspect is noted accordingly, multiplier factors (MF) were calculated by multiplying the weight taken into account for each criterion by the score of each aspect divided by the maximum score for each environmental, technical, economic, and social aspect of different "infectious waste treatment technologies," the most important criteria in selecting the best technology are "environmental" and "economic" [22]. In another study, "statistical analyzes are performed to evaluate the rates of generation and composition of medical waste generated during the treatment of the coronavirus pandemic" with reference to a care hospital from Jordan.

An average of the resulting medical waste is "3.95 kg/bed/day", a value 10 times higher than the "generation rate in the hospital during regular daily surgery". This high value of medical waste is largely attributed to the medical staff of the hospital using disposable personal protective equipment [31].

It is assumed that pharmaceutical waste also has an influence on the generation of medical waste; this may be partly due to patients who do not use the drugs properly; also, another cause would be the wrong prescription of drugs. This issue is currently being studied, but further investigation is needed [33].

## 3. Discussion

After the bibliographic research on the subject of interest and after the directions of its separation in M, E, and D were determined, we proceeded to the systematic, critical analysis of the valuable ideas, the role of this analysis being to create a central concept to which this scientific research by the authors directs.

There was significant interest from researchers from various countries such as China, Palestine, Iran, Turkey, Taiwan, Tanzania, Brazil, Indonesia, Ghana, South Korea, Romania in research aimed to establish sustainable management of medical waste resulting from the COVID-19 pandemic. These populations being in various situations: state of emergency, state of alert, quarantine at home.

### 3.1. M—Management

The management of COVID-19 in Romania, in a state of emergency, between 16 March and 14 May 2020, imposed a national blockade with restrictive measures and social distancing, with a great strict restriction on population mobility, only justified and minimal travel and having only reduced economic activities, the population entering technological unemployment [4]. A rapid assessment method of potentially infectious waste flow, the importance of medical and municipal waste management systems, and services in combating the community's COVID-19 virus were necessary [4]. In our opinion, the Romanian situation in waste management was a challenge, considering the novelty of the pandemic and the waste flow being influenced by the government experience in establishing procedures.

The authors of [6] express the importance of the accuracy of the data in the territory in order to have a future image regarding the estimation of the variation of these values. If in 2017 the amount of medical waste was 280 t, almost double compared to 2011, obviously this value is different now, especially in the context of the COVID-19 pandemic. The authors also analyze the amount of medical waste by age category and GDP% per capita (from $11.2 in 2011 to $10.5 in 2017). The EKC model (environmental Kuznets curve) gives a good appreciation of medical waste quantity per year, per bed-day, per capita, and also for an appreciation of GDP% to spend/year [6]. The model created is based on: the number of patients, bed occupancy rate, medical waste amount, waste amount establishes by the bed, person, day. It is a good experience of what the costs of waste management are in Turkey in comparison with other countries.

As for impact [34] on the environment, it can be noticed that measures of social distancing, isolation, quarantine, alertness, and urgency were quickly taken. In this way, it was observed that carbon emissions in the environment decreased significantly due to the decrease in cars, motorcycles, air transport, etc. The impact on health has materialized in the form of the increase in health, salary, sanitation, and cleaning costs when comparing various countries that are hard hit.

The economic impact consists of the allocation of additional funds for health, restored monetary policies, procurement priorities, the creation of social assistance programs, and limiting unemployment. As a result, it is necessary to determine the losses caused by COVID-19 and return to economic growth, environmental, and social conditions in the post-COVID-19 period. The model created by the authors HU L et al. shows us that age and sex are not very important in no-show behavior. It can be appreciated that the comfort aspect has particular importance. The channels for establishing the hospital–patient connection are not to be neglected. Finally, the authors added a no-show habit as an unconscious determinant. Our research has implications for managing patients' no-show behavior, improving the hospitals' management, and establishing a communication system between hospitals and patients.

The results of the research suggest the need for immediate installation of temporary incinerators, which may be an effective solution for managing the increase of medical waste during the COVID-19 outbreak in Wuhan, but the location selection of these temporary incinerators is a critical problem. The question is: Where to install storage points and incinerators? Due to the limitation on available data and knowledge at the present stage, more real-world information is needed to assess the effectiveness of the current solution [13].

Jason Corburn et al. [14] propose some measures for ways to protect residents of urban settlements, poor people, those who are living in poor conditions, and the population exposed to COVID-19:

—- institute informal settlements/slum emergency planning committees in every informal urban settlement;
—- apply an immediate moratorium on evictions;
—- provide an immediate guarantee of payments to the poor;
—- immediately train and deploy community health workers;
—- immediately meet Sphere Humanitarian standards for water, sanitation, and hygiene;
—- provide immediate food assistance;
—- develop and implement a solid waste collection strategy; and
—- implement a plan for mobility and health care immediately. Lessons have been learned from earlier pandemics such as HIV and epidemics such as Ebola" [14]. It is very known that at the beginning COVID-19 was treated as a respiratory affection, or one with a symptomatology near to Ebola, with medical researches on patients/posology.

The role of research is to show that used sanitary products can be reintegrated into other products through recycling, for example, syringes and other dangerous medical articles made of plastic or glass. This has been demonstrated (concrete forms added with plastic/glass have a hardness 30–50% higher than those without plastic) and leads to the

idea of informing decision-making bodies in developing procedures to be used by recycling hazardous medical materials [16].

The authors, following laboratory analyses undertaken through a generous program, established a new treatment method for flying ash resulting from incineration. The scaling method consisted of two processes; phosphoric acid treatment followed by washing with water, which is able to stabilize the flying ash.

This method has been successfully applied for the stabilization of Municipal Solid Waste Incineration (MSWI) flying ash and was used for Medical Waste Incineration (MWI) fly ash treatment [32].

The study presented in [23] is useful to estimate the amount of MW in the next period in order to design the flux of waste, future treatment, storage facilities, incineration capacities. The ARIMA (0, 1, 2) model with the lowest RMSE (763.6852), MAD (588.4712), and MAPE (11.7595) values and the highest R2 (0.9888) value showed a superior prediction performance compared to SVR, Grey Modeling (1,1), and LR analysis.

The results obtained from the models indicated that the total amount of annual medical waste to be generated would increase from about 26,400 tons in 2017 to 35,600 tons in 2023 [23].

The study presented in [24] makes two significant contributions. First, the study introduces the GSCM, an innovative green concept to healthcare, very useful for hospitals. Second, the study applied the dynamic Taguchi method to the EMS and neural network (NN) to construct a model revealing the relationship between factors—cause—and performance—effect [24]. Results obtained by researchers show that medical waste is an accumulation of Cu, Cr, Pb, and As in the tested soil samples. Compared to the controls, the samples collected from different areas containing medical waste were significantly enriched with ARGs annotated as sulfonamide and multidrug resistance genes, and in particular, in two subtypes. The comparatively higher abundance and diversity of ARGs in contaminated soil poses a potential risk to human health [25].

Based on achieved results, ozone was highly influential on microbial decontamination compared to peracetic acid and NaOCl disinfectant and can be used for the disinfection of DUWLs [29].

### 3.2. E—Exposure to Medical Waste—RISKS

According to Mihai, a COVID-19 waste monitoring model can reduce the risks of contamination of medical staff and the environment [4].

Equivalence and management of PPE used as infectious waste have an essential role in preventing indirect COVID-19 infection, according to the WHO (World Health Organization) guidelines. This establishes the flow of medical waste in direct causal connection to COVID-19. The principles of COVID-19 waste management are sustainability, transparency, and safety. Masks used in households should be disposed of separately from other waste and incinerated or disposed of in landfills [9].

A study recommends the organization of regular training courses for health workers. An interconnected approach is needed in medical waste management (hospitals, Ministry of Health, companies engaged in the collection, transport, and disposal of medical waste) [10].

Waste management of individual cloth masks should be done in the same way as standard operating procedures for medical waste. Proper management of individual masks decreases the potential danger of SARS-COV-2 spread [15].

Standardized management of medical waste related to COVID-19 can decrease the danger of disease in hospitals [28]. This standardized management can be realized based on experience from different countries to harmonize the medical and social politics, thus being useful to people affected by COVID-19. Psychically, people are influenced during the different periods, lockdown, quarantine, alert estate, and this can be a real and huge problem for medium and long periods.

This medical waste, incorrectly managed, poses a risk to medical staff and public health. A study identifies the increase in medical waste during COVID-19 with the pandemic's evolution [35].

### 3.3. D-Distribution

The management of uncertain parameters is done with a new programming approach called "RPP", also applying the "fuzzy objectives" method. Therefore, for "uncertain amounts of medical waste, the optimized number and location of facilities and types of technologies in treatment centers are determined" [2].

Steam sterilization is considered the best technology for treating waste generated by the medical industry, among the four sustainable options. Microwave or ultraviolet heating systems are the second option, incineration and storage being the least sustainable [3].

The waste generated following this pandemic of COVID-19 requires the collaboration of all parts of a management system. Disposable masks, gloves and coveralls, and other hospital equipment should be disposed of separately from other waste by guided workers with special equipment with the red symbol [9].

## 4. Conclusions

There are few types of research related to hazardous waste management directly associated with COVID-19, since the onset of this pandemic. Examples were found from several countries worldwide, such as China, Taiwan, Turkey, Iran, Jordan, Tanzania, Brazil, Palestine, Kazakhstan, Indonesia, Ghana, South Korea, Romania, which address the various issues presented in the paper. An investigation into the experience of some Western European states, as attacked by the virus, the USA or Japan, would have been useful. The examples would have helped create a procedure as simple as possible, economical, and with impact effects on humanity being as friendly as possible.

The risk of becoming ill with SARS-COV-2 can be reduced through the correct management of medical waste resulting from both specific activities in hospitals and the use of masks in quarantine and isolation locations as well as in daily activities, depending on the legal regulations in each country. Additional studies are required to guide the proper management of COVID-19 medical waste from households and non-medical institutions.

Selective waste collection is a topical issue with a significant influence on both humanity and the environment, having the most significant role in the process of disposal. Because the COVID-19 pandemic has generated a huge amount of hazardous waste, it is necessary to replace the current disposal methods, for example, the incineration method, which pollutes the air by releasing many toxic compounds into the atmosphere or the storage method, a real danger because the toxic compound remains in the groundwater for a long time. The technique that would have helped a lot during this pandemic is the steam sterilization of hazardous medical waste, so the process would have been controlled and carried out under certain conditions, preventing the dispersion of hazardous compounds.

Because existing studies have shown the resistance of the COVID-19 virus over time on various surfaces, a real problem is still the disposable masks used, the management of this problem is still under development. Despite being a source of this virus, their collection in specially arranged spaces and in due time is done with great difficulty, especially in Romania, where, unfortunately, these potentially hazardous wastes end up in the same place as the rest of the municipal waste.

Even if the financial effort of each country is considerable, for the protection of people and the environment, it would be useful to develop clear transport procedures, protected routes, intermediate collection points (if applicable), and short storage in destruction areas (the concept of "destroyed waste, zero waste" is useful).

Therefore, a joint human effort is needed to develop COVID-19 hazardous waste management procedures, to ensure transport security, to simplify material and human costs, to develop ways to dispose of this waste, and to use it in a sustainable, innovative way, so that the environment is not adversely affected

The limitations of this study are determined by the fact that only the Web of Science database was researched.

The authors provide a critical study on the new approach to medical waste during COVID-19. This study can help develop the following research directions in this field, creating international interdisciplinary teams based on which researchers can contribute to improve and prevent the implications of medical waste in society, medicine, and industry. Researchers may use the same research method for other topics as well. The article can also be beneficial for Ph.D. students and might be of some interest to practitioners.

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