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RESEARCH ARTICLE

Municipal solid waste and risk from 1970 to 2020

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Abstract: Risks have been addressed from at least 5 different approaches, including environmental, health, occupational, chemical and technological standpoints, each using their own definitions, which limits the design of public policies focused on improving MSW management. The purpose of this paper is to analyze how the concept of risk is used in different investigations in the field of MSW. The factors that influence these concepts are also determined, including the spatial context of risk assessments. The search focused on 73 scientific papers from journal pages to specialized search engines, such as Google Scholar or ScienceDirect, published between 1970 and 2020. Throughout this period, many changes, mostly brought about by economic and health crises, can be seen. A significant risk increase is observed in the 1980s with a marked rebound in the early 1990s, which continues throughout the following decades. Risks increased drastically in parallel with unemployment and mortality in 2020, due to the global pandemic, which modified waste composition, since protective equipment against coronavirus was mixed with household waste.

Keywords: exposure, final disposal, hazard, leachate, municipal solid waste, vulnerability

1 Introduction

Municipal Solid Waste (MSW) has gained relevance in recent years, not only because of the large amounts of waste that are being produced in various parts of the world, but also because of the serious damage caused to the environment and human beings. Gouveia and Prado [1], Jiang et al. [2] and Palmiotto et al. [3] address the affectations of human beings, which range from olfactory discomfort and physical damage to the generation of various types of cancer. Vongdala et al. [4], Przydatek [5] and Kumar et al. [6] analyze their effects on other components of the environment, such as soil, water, air, vegetation and fauna. According to Araiza et al. [7], all these damages can be considered risks derived from MSW mismanagement.

Unfortunately, those risks have been addressed by several disciplines, with varying definitions of their components, which generates confusion [8]. This occurs even in the case of a concept such as MSW, which can be defined with terms like environmental impact and environmental risk, in addition to hazard, danger and threat, especially in non-English speaking countries [9,10].

In the context of risk assessments, there is also often confusion, mainly because of the techniques and the geospatial scale used to model the risk. For example, in the manuscripts of Kiryushina et al. [11] and Kazuva et al. [12], matrix techniques are used to determine the risk, while in Vaverková et al. [13] and Cangialosi et al. [14] they use mathematical formulations that associate the chemical characteristics of some hazardous agent (leachate or biogas) with cancer events in human beings and other damages in living organisms. In another context, the works of Rapti et al. [15] and Bosque et al. [16] use different scales, spatial models, hazardous agent or receptor of damage (human or environmental) to model the risk associated with MSW.

The foregoing causes terminological ambiguity, which prevents the correct design of public policies focused on improving MSW management. The purpose of this paper is precisely to analyze how the concept of risk is used in different investigations in the field of MSW. The factors that promote these concepts are also determined, including the spatial context of risk assessments.

2 Materials and methods

The survey of scientific works (73 papers and technical reports) was carried out from various pages of journals and specialized search engines, such as Google Scholar or ScienceDirect, after having prepared a list of terms or keywords (See Table 1). The search targeted papers published between 1970 and 2020, in order to cover a relatively broad set of publications.

The analysis focused on identifying the different approaches to risk associated with MSW, as well as the factors that lead to the emergence of such approaches. Finally, a review of the particularities of the spatial analysis of the risk associated with MSW was also carried out.

Table 1 Keywords used in the search for papers via the internet

Main words	Secondary words
Municipal solid waste	Collection, final disposal, incineration, infrastructure, landfill, landfill gas, leachate, storage, transfer, transportation.
Risk	Assessment, damage, environment, exposure, fragility, hazard, impact, public health, sensitivity, threat, vulnerability.

3 Results and discussion

3.1 The concept of risk in the literature of waste

Figure 1a shows the behavior of scientific texts that address MSW-related risk. A significant increase is observed in the 1980s with a marked surge in the early 1990s, which continues growing in the following decades. The foregoing is due to two factors: first, the policies that permeated the area of anthropic risks, based on the provisions of the United Nations General Assembly, within the framework of the international decade for the reduction of natural disasters (1990-1999); and second, the various ecological initiatives that also appeared in this decade, for example, the Rio de Janeiro declaration in 1992 and the Kyoto Protocol in 1997, which were important because they introduced new concepts such as environmental impact and sustainable development [8].

In the reviewed literature, four approaches to risk were identified, such as i) environmental and ecological risk, ii) epidemiological and sanitary risk, iii) ergonomic or occupational risk, iv) chemical and technological risk, which are described in Table 2. A fifth approach (environmental impact or safety) was also identified, which refers to MSW impacts in a generic context, which may be susceptible to misinterpretation.

Table 2 Risk approaches found in the literature

Risk approach	Description	References
Environmental and ecological risk	Articles based on this approach to risk address the damage to humans, flora and fauna caused by toxic agents that are present in contaminated sites. The methods developed by international agencies to assess risk at contaminated sites have influenced them. In fact, they have created a series of stages for their execution, such as: I) hazard identification, II) dose-response assessment, III) exposure assessment, and IV) risk characterization. The characteristics of the toxic agent and the damage receptor are very important.	[17] [18] [19] [20] [21] [22]
Epidemiological and health risk	This risk approach addresses human diseases caused by MSW, and also considers their propagation. Damages are normally produced by indirect contact with MSW, for example, through the proliferation of vectors such as flies, rodents and mosquitoes that can favor dengue, typhoid fever, salmonellosis and dysentery. Respiratory affectations and various types of cancer are also considered in people living near MSW management facilities. It is important to mention that all damages are analyzed within the framework of epidemiology, that is, identifying how a disease is distributed according to time, place and characteristics of people.	[23] [24] [25] [26] [27] [28] [29]
Ergonomic and occupational risk	This risk approach is related to damage to people by direct contact with MSW, particularly during collection, transportation and final disposal of wastes. Formal jobs are usually analyzed more frequently than informal jobs (pickers or recyclers). Back, legs, shoulders and arms are the body parts usually affected. Hand lacerations and cuts are also common, as well as the appearance of cutaneous ulcers and irritation of the respiratory tract.	[30] [31] [32] [33] [34] [35]
Chemical and technological risk	This type of risks occurs in case of infrastructure failures causing liquid, solid or gaseous emissions that affect human beings and ecosystems. Some examples of this type of infrastructure are the final disposal sites, the separation plants or incinerators. Normally, damages occur through indirect contacts, therefore, to evaluate this risk it is important to know the characteristics of the MSW management infrastructure and the emitted toxic agents.	[16] [36] [37] [38]
Environmental impact or safety	This risk approach addresses ecosystem affectations, but in a generic context. This happens because sometimes the terms of impact and risk are used without distinction. Other Papers use specific environmental impact assessment terminology, therefore, there are no misunderstandings with the terminology used.	[39] [40] [41] [42] [43] [44] [45]

The literature reviewed suggests that humans are considered the main receptor (43%) of the damages caused by MSW (Figure 1b), whose effects can be caused by direct or indirect contact, for example, by inhalation, ingestion, dermal contact, and by interaction with disease transmitting vectors. The atmosphere is also mentioned as a potential receptor of damages by MSW (13%), particularly by gaseous emissions of methane or volatile organic compounds. Water was considered as receiving damage in several papers (9%), which mainly deal with leachate dispersion and its effect on groundwater, leaving aside the contamination of surface waters. Vegetation was only considered as damage recipient in a few papers (3%), which analyze the deterioration of plant species due to the entry of gases into the tissues during photosynthesis and respiration. Finally, the soil is not usually considered as damage primary receptor, despite the fact that MSW is deposited directly on it. Fauna, on the other hand, is more readily considered as a vector that causes discomfort than as a damage recipient.

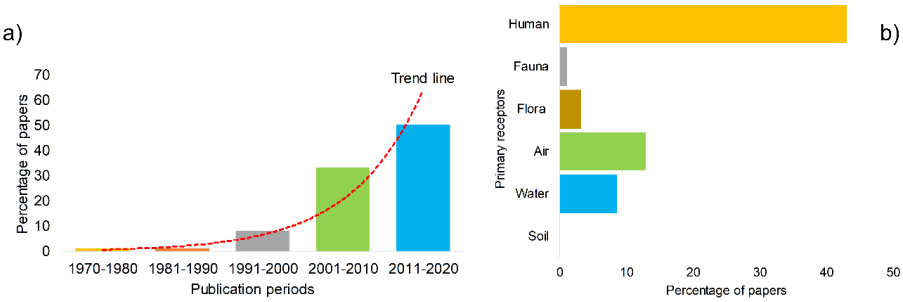

Figure 1 Temporal distribution of papers related to risk (a) and MSW and by affected receptor (b)

3.2 Factors causing the existence of various approaches to risk

The first factor that leads to the existence of several risk approaches is the still young nature of the concept. It is known that the risk and its components are still evolving, despite existing well-founded theoretical bases. For example, Burton and Kates [46] and White [47] established the conceptual bases of what is now known as risk and danger. Undro [48], Quarantelli [49–51] and Maskrey [52] also contributed to the development of theoretical bases, because they generated new concepts such as vulnerability and new ways of approaching risk through social aspects.

The second factor that significantly influences the formulation of the concept of risk associated with MSW, is the legislation of the countries. For example, in Mexico and the USA, the environmental and ecological risk approach is the most used in risk assessments, which is influenced by environmental laws and regulations in those countries. (General Law for the Prevention and Integral Management of Waste in Mexico [53] and Resource Conservation and Recovery Law in the United States of America [54]). The development of risk assessment methods in contaminated sites, such as those developed by EA [55,56], IEEPA [57], USEPA [58–60] and OPS [61] have also influenced the use of some risk approaches. These methods have been well accepted in the country of origin and their conceptual bases have been transferred to laws and regulations of other countries.

The third factor that influences the use of the concept of risk, is the waste management stage in which the damage occurs (collector truck, treatment plant or final disposal site). For example, in the scientific literature, risk assessments have been carried out in Landfills or Open Dumps, because of the interest in identifying and evaluating the damage caused by this type of infrastructure. Additionally, the landfill is usually the most commonly used waste disposal method in the world [62].

The damage receiver (human being or ecosystem) can also condition the use of certain techniques, methodologies or risk approaches. This can be seen in the articles of Chen et al. [63] and Araiza et al. [64], where mathematical dispersion models and characteristics of a toxic agent present in the waste are used. In other cases, where the human being is the damage receiver, mathematical indexes that consider factors such as the variability between individuals, for example, age, sex, race and lifestyles, etc. are used [65].

Finally, the characteristics and byproducts of the MSW also influence the formulation of risk associated with wastes. The year 2020 witnessed the arrival of drastic changes of habits, caused by the COVID 19 health crisis. This provoked the mixture of the usual MSW such as plastics, cardboard or organic matter, with other hazardous products, such as masks, empty gel bottles, alcohol, cleaning products, expired drugs and others. Prior to the pandemic, hazardous

products represented a small share of the MSW composition (0.2 to 5% by weight) (see references [66–71]). This share is now probably twice as big.

3.3 Spatial analysis of the risk associated with MSW

Risk spatial modeling can be traced back to the 1980s, when a great variety of threats and risks were modeled, particularly those generated by natural phenomena [72]. The spatial modeling of the risk derived from MSW is recent, so there are still difficulties regarding the use of techniques and appropriate scales.

The works of Bosque et al. [16] and Díaz and Díaz [38], deal with the chemical and technological risk approach. A theoretical framework is developed where the "vulnerability and exposure" components play an important role. The authors propose a simple procedure based on the calculation of distances within a Geographic Information Systems, to establish areas potentially exposed to risks in the territory (risks due to the presence of landfills, incinerating plants, etc.). These works are important starting points; however, the concept of scale and the type of variables that must be employed are not very clear.

On the other hand, the papers of Butt et al. [18–21] deal with the environmental and ecological risk approach. The authors try to adapt each stage of risk assessment to spatial analysis, endeavoring particularly to develop a theoretical framework for landfills. However, due to complexity of this risk approach, it is not clear how it should be done. The modeling scale and variables are also confusing.

More recently, Araiza et al. [7] and Araiza et al. [73] also proposed a theoretical framework to model the risk associated with MSW, through an approach that is different from those mentioned above. The authors make the use of spatial scales and the source of obtaining data very clear. For example, for regional studies, they suggest using socio-demographic, economic, cultural and physical variables, which can be obtained from databases compiled by government agencies. In local studies, more detailed physical and social variables can be used, which are obtained from interviews and other field work. Finally, in the studies of small size sites, field work and laboratory are generally used, as well as the models of mathematical dispersion.

4 Conclusion

This paper reviews how the concept of risk is used in different researches in the field of MSW (1970–2020.) The factors that promote these concepts are also determined, including the spatial context of risk assessments.

The most important conclusions are summarized below:

(1) 5 risk approximations were identified in papers that address the topic of MSW, which shows that there is no common language. These approaches are: (i) environmental and ecological risk; (ii) epidemiological and health risk; (iii) ergonomic and occupational risk; (iv) chemical and technological risk; and (v) environmental impact or safety.

(2) There are factors that influence the use of the various risk approaches associated with MSW, such as: (i) environmental laws and regulations of countries and regions; (ii) the stage of waste management where damage occurs; (iii) the type of damage receiver (human being or environment); and (iv) the characteristics or components of the MSW.

(3) The spatial modeling of the risk derived from MSW is recent, so there are still difficulties regarding the use of techniques and appropriate scales.

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Conflict of interest

The authors declare that they have no conflict of interest.

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