Mortality Due to Meteorological Disasters in Mexico during 2000-2015

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Abstract

This document aims to examine the changes in mortality induced by several extreme weather events from 2000 to 2015 in Mexico and analyze the characteristics of the victims, as well as the demographic and geographical vulnerabilities for the development of adaptive and preventive strategies for geographies and specific population groups to minimize the effects of extreme weather. The results show that mortality from natural disasters remains unacceptably high, since most of these deaths could have been prevented. The lethality of disasters occurs not only due to exposure to a certain threat, but also due to the accumulated vulnerability of certain populations. Taking into account the results of the research, prevention programs should target men of productive ages and older adults, women in particular to girls under nine years of age and older adults, which would reduce the impact on mortality due to meteorological disasters.

Keywords: Disasters, Vulnerability, Mortality

1. Introduction

Mexico is a region highly exposed to multiple hazards of natural-seismic and hydrometeorological and socio-natural origin, said hazards have been growing due to climate change, that intensifies the phenomena related with the heavy rains and prolonged droughts events with an immediate and long term impact in the more vulnerable populations.

The projections made to this day suggest that Mexico will be severely affected by the global climate change, with important variations in average annual temperature and precipitation during this century (McCarthy, 2001; Emanuel, 2005; INE-Semarnat, 2006; Magrin et al., 2007), in combination with tropical storms and droughts of greater intensity (INE-Semarnat, 2006; Rojas-Rodríguez & Hurtado-Díaz, 2006; Magrin et al., 2007).

Mortality is the ultimate expression of disaster. According to the Network of Social Studies in Prevention of Disasters in Latin America (2018) during the last half century, the disasters have produced in Mexico more than 17 million victims, another seven million wounded, more than 50 thousand dead and 10 thousand missing.

This data reminds us the strong impact that disasters have over the life and development of the different regions of the country, however, the research over the impact of the deaths related to external climate events is vastly limited. The studies of damage caused by meteorological disasters usually approach the economic losses and few times examine the social factors of the disasters in relation to the victims and the vulnerable groups.

The present document has as objective to examine the changes in the mortality induced by various external climate events from 2000 to 2015 in Mexico and analyze the characteristics of the victims by sex, age, level of education, occupation and the different regionalities. Data about the number of deaths by meteorological disasters collected by the Secretary of Health (Secretaría de Salud, SSA) and the National Institute of Geography and Informatic (Instituto Nacional de Geografía e Informatica, INEGI) will be used.

The results of this study will contribute to the development of adaptive and preventive strategies for geographies and populational groups specific to minimize the effects of extreme climates.

1.1 Theoretical Framework: The Meteorological Disasters and Social Sciences

From the point of view of the contribution that the social sciences make to the studies of the disasters in Latin America, exists an absence of studies about the social nature of the disasters, due to the dominance enforced by the natural and basic sciences over the problem of the disasters in Latin America that is almost total.

The society does not appear in the formula, neither as an object of study nor as an object of action and change in terms of their patterns of behavior and the incidence in the concretion of situations of disaster. The reasons of this lack of attention include:

- The strange, unpredictable and sudden of the occurrence of a disaster;
- The conception that the behavior of nature and its impact cannot be controlled;
- The difficulty to get useful data about the consequences of the disasters during its development and immediately after.

Disasters are not conceived as an integral part of the spectrum of human-nature relations or directly dependent on them, but rather as a problem temporally and territorially limited, something rare or extraordinary, "events that violate normal life and its relations with the habitat".

The interest in disasters by students of the social sciences has been temporary and almost forced by the importance or visibility of the event of great magnitude (for example, the earthquake in Mexico in 1985), so it has not been recognized as a generic topic of permanent study in the social sciences. A necessary step for the construction of the relationship between the social sciences and disaster is the social conceptualization of disaster, that is, the characteristics that define it and the conditions necessary for it to exist.

The disasters have an impact in the territory characterized by a *vulnerable* social structure and where the intern differentiation of the society influences in an important way in the damage suffered and in the social groups affected in big or small grade. From this perspective, a disaster is as much a product as a result of social process, historical and territorially circumscribed and shaped.

A disaster can be defined as:

- An occasion of crisis or social stress, observable in the time and space, in which societies or their components (communities, regions, etc.) suffer damage or physical loss and alterations in their routine, altering the functioning of the human community affected and exceeding its capacity to confront the situation using their own resources. The causes and the consequences of the disasters are a product of social processes that exist in the interior of the society (Lavell, 1993; EIRD, 2007).

1.2 The Vulnerability a Concept Linked to the Study of the Disaster

The vulnerability of the population and their exposition to the risk of suffering some disaster differ according to the subgroups of population because of some characteristics sociodemographic such as the age, the sex, the ethnic, level of education and others of contextual type such as religion. In addition, it would be necessary to add the physiological susceptibilities of the geographical space that is inhabited, socioeconomical, psychosocial factors, exposition and perceptions to the risk and the answer’s capacity.

The differential vulnerability is determined by the demographic characteristics socially constructed and the norms associated to these characteristics. For example, the women exhibited a bigger susceptibility to the heat waves (Michelozzi et al., 2005). In return, the men have bigger risk of mortality caused by inundations and storms than women, seeing as men participate more frequently in outdoors activities and therefore, have a bigger exposition to hydrological disasters (Zagheni et al., 2015).

The focus of vulnerability has been highlighted as key in the sustainable development, both in the World Summit on Sustainable Development of the United Nations in 2002 (Lutz & Shah, 2002) and a decade later for RIO + 20 Earth Summit (Lutz et al., 2012). It results necessary to incorporate the concept of differential demographic vulnerability in the analysis of the vulnerability and the political measures aimed to reduce the vulnerability in consonance with the Sustainable Development Goal 10 about equality for everyone.

The vulnerability of the locals cannot be measured directly in real time, seeing as the disasters are prone to be complex phenomena that behaves, in most cases, in an esoteric way because of the scales space-time of the systems involved (the physical and the social) often are varied and asymmetric. (Kienberger, Blaschke, & Zaidi, 2013).

In different geographical latitudes efforts have been made to clasify or tipify the distinct vulnerabilities with the purpose of helping prevent the disasters, at the beginning of last century Schmidtlein, Deutsch, Piegorsch, & Cutter (2008), divided the types of vulnerability in two broad categories:

- Biophysical, referring to the exposition that each person has to some external process;
- Social, linked to the constructed environment, to the public policies and the human ecology. The social vulnerability tends to manifest when the environment burden (geodynamic phenomena such as: tsunamis, floods, mud flows, typhoons, among others) surpasses any other type of genetic sensibility and social order.

In Latin America, Chaux (1998) attempted to understand the complexity of the approach, making the study of disasters even more problematic by concluding that the vulnerabilities of one system were the threats of another and vice versa, for example, hydroelectric dams usually reduce the socioeconomic vulnerability of the distant localities that benefit from the arrival of electricity supply, but, at the same time, the localities close to said hydroelectric dams increase their medical vulnerability due to vectors of zoonotic diseases have greater spaces for their reproduction.

Other authors have attempted to go beyond, developing some social vulnerability indexes to compare and evaluate the condition of social vulnerability that is manifested by one or more localities in a space-time context (Cutter, Boruff, & Shirley, 2003). However, they face methodologic difficulties, such as: the necessity to justify the quantitative indicators selected to the confection of the index. (Note 1)

Is necessary to consider that any metric involving the vulnerability depends on the availability of the data, which causes a continued and systematic elaboration of measurements for each place (Chau et al., 2014). For this reason, is useful to give emphasis to the geostatistical analysis of some and the exposition to the forces of nature, such as: mortality rate, rate of victims, density of injured per unit of area; among other values of parametric character, to geographize and invigorate researches.

The statistical analysis of a given territory helps to clarify the phenomenon of social vulnerability (Álvarez & Cadena, 2006), this is due to the fact that an index combines a series of variables, which makes it possible to assess a set of factors in a single measurement, which can be used or help to make decisions.

Within the disasters, death is the maximum expression of the event, in this research we work with all the deaths that occurred in Mexico during the period 2000-2015 for any of the ten causes due to *exposure to forces of nature*, classified in this way by the World Health Organization, and is part of the emerging sciences dedicated to the study of the relationship between society and nature.

To reduce the risk of the population of suffering the lethality of disasters is necessary to identify the recurrent variables, it is also necessary to increase the security and the resilience of the communities. The lethality of the disasters is produced not only by the exposition to certain threats, but also by the accumulated vulnerability that some populations are in.

1.3 Referentes Empíricos Sobre las Muertes por Desastres Meteorológicos

The meteorological disasters are an important component of climate change that affect the mortality rates (Kovats, Campbell-Lendrum, & Matthies, 2005). However, there are few studies in social sciences that evaluate the causes and characteristics of the people dying for this kind of disasters, generally addressing only the economic losses.

Most of the researches about extreme climate events have centered in a specific geography, a meteorological disaster or a period of time in particular. For example, the study of Goklany (2009) examined the tendencies in the number of deaths and the mortality rate for every kind of disaster, like draughts, floods, storms and hurricanes for the period of 1900 to 2008, concluding that deaths by disaster have a decreasing tendency.

Despite the downward trend in human casualties, countries are susceptible to significant loss of life due to extreme weather events, as evidenced by Hurricane Katrina, the heat wave in Europe in 2003, the heat wave in Chicago in 1995 and the earthquake in Mexico City in 2017.

In the United States, two studies stand out, the first one elaborating the spatial patterns of mortality by natural hazards at the county level for the United States from 1970 to 2004 using a combination of geographic and epidemiological methods (Borden & Cutter, 2008); while in the second, several disasters are analyzed for more than 25 years, evaluating the characteristics of sex, race and age, as well as vulnerable areas (Thacker, Lee, Sabogal, & Henderson, 2008).

However, these studies did not evaluate the specific causes of death according to different kind of disasters, for example, heat, lightning, floods or storms how others have done, that are mentioned in the following paragraphs.

Díaz et al. (2002) explored the relation between heat and mortality in Sevilla (Spain), concluding that the increase of mortality happens suddenly, especially in older people, from 36.5 to 41ºC of maximum temperature; meanwhile Azhar et al. (2014) studied the same relation in Gujarat (India), finding that the heat wave of the summer of 2010 caused a large amount of mortality because of the limited geographical and temporal scope the findings of both researches are not generalizable.

Similarly, Michelozzi et al. (2005) studied the impact of the heat wave in mortality for specific causes and the role of the demographic characteristics and the socioeconomic conditions that could have increased the risk of mortality in four Italian cities: Bologna, Milan, Rome and Turin for the year 2003. Their results showed that, elder people of age groups 75-84 years old and 85 years old and more where the age groups more affected; the mortality rate was bigger between women; the bigger increase in mortality was registered in people with a poor socioeconomical status (Roma + 17.8%) and with lower educative levels in Turin (+ 43%).

Ahmadalipour and Moradkhani (2018) made a measurement of the risk of mortality associated with the stress because of excessive heat in the Middle West and North Africa for people older than 65 years, finding that the risk of mortality will increase from 8 to 20 in the first 30 years of the XXI century with respect to the historical period 1951-2005. The authors suggest that a big part of the increase in the risk of mortality is due to the increase in the frequency of the warm days instead of their intensity.

In the other hand, Singh and Singh (2015) examined the deaths by lightning in India in the period of 1979 to 2011, the results show that a significant number of men (89%) has died by lightning compared to women (5%) and children (6%), which is more probable because of the large proportion of men that work and move outdoors and on their own.

Zagheni, Muttarak and Striessnig (2015) instead evaluated the period of 1995-2011 in 63 countries the patterns of mortality of the hydrometeorological disasters in populations through the dimensions of age, sex, and human development. They found that the mortality rates for hydrometeorological disaster for the men are consistently higher than for the women in all age groups and that the differential for sex is higher for adults than for the young children or the elders.

The studies mentioned have provided important information about the impact that the extreme climate events can have in human life, but detailed information about vulnerable groups is still lacking. The different periods of study, spatialities and methodological differences difficult the comparison of results in this works.

Is difficult to find researches that analyze every cause of death of all the natural risks and the sociodemographic characteristics during a large period and a broad geographical coverage, beyond the accumulation of the number of victims of meteorological disaster. Although there are some exceptions, for example:

▪ Myung and Jang (2011) analyzed the specific causes and demographical and regional characteristics due to meteorological disasters in South Korea between 1990 and 2008, they found that the flood caused the biggest number of deaths, a tendency that is changing to typhoons. The factors associated with a larger vulnerability are associated to people residing in coastal provinces, more aged and of male sex.

▪ While Mahapatra, Walia, Saggurti (2018) calculated the mortality related with extreme climate events registered in India during 2001-2014, employing as analytical variables the region of residency, the age and the sex. The research concludes that the majority of the deaths induces by extreme climate events where due to lighting strikes, followed by precipitation and very high or very low temperatures; there is a male over-mortality; the people adapt to some meteorological phenomena, like the cold waves and the cyclones.

Most of the studies made about the mortality caused by natural hazards in Mexico, have centered in a specific type of meteorological disaster, like the heat. Three researches stand out in this line, in the first Rojas-Rodríguez and Hurtado-Díaz (2006) elaborated a diagnostic about the effects of climate change in human health of the population of Mexico and examined the deaths by heat stress during the period of 1979-2003, concluding that 1998 was the year where more deaths by heath were registered and that the states of Baja California where the entities that concentrate the largest number of this type of deaths.

Rojas-Rodríguez and Hurtado-Díaz, 2006 in the second point out that the increase in the environmental temperature increase the mortality by heat stress and a bigger incidence in cases of dengue, malaria and diarrheal diseases, besides of a bigger mortality by respiratory diseases related with the increase in the environmental temperature and the atmospheric contamination.

In the third research, Díaz, Castro and Aranda (2014) analyzed the impact of the high temperatures in the mortality during the period 2002-2010 and identified 393 deaths of people cause by the excessive natural heat, for the most part located in the nor east of Mexico, men with a low socioeconomic level.

Based on the context presented is relevant to examine the changes in the mortality by meteorological disasters, as well as analyze the characteristics and regional differences of the people that died according to the types of disaster occurred during the period of 2000-2015 in Mexico.

2. Method

In Mexico there exists different types of administrative records about statistics of diverse topics such as, *public security and justice* (delivery of justice in criminal matters and public bodies of human rights); *economy* (land transport accidents in urban and suburban areas, trade balance of merchandise of Mexico, exports by state, metallurgical mining industry, profile of export manufacturing companies, program of the manufacturing industry, maquiladora and export services (IMMEX), livestock slaughter in municipal trails, urban transport of passengers and motor vehicles registered in circulation); *social* (museums, labor relationships of local jurisdiction and health in particular establishments); *history* (culture, maquila industry of exportation, suicide attempts, suicides and criminal proceedings in criminal matters); and vital facts (natality, nuptiality and mortality), which are updated periodically (INEGI, 2019).

Among the administrative records mentioned the vital facts and in particular the mortality statistics were fundamental for the development of this research being the primary source of information. The statistics about death are accounted in Mexico since 1893 to this day, though there are available data in database format since 1985 (INEGI, 2018).

The government entities in charge of systematize and elaborate the statistics about deaths in Mexico are the Health Secretary (Secretaría de Salud SSA) and the National Institute of Geography and Informatic (Instituto Nacional de Geogafía e Informática INEGI), to whom by law every time that a death occurs the civil registry sends a copy of the death certificate, so that they capture the information of the dead person.

The death certificate is an essential requirement to bury or cremate a person and must be filled out by a medic who must note the specific cause of death and some characteristics of the dead person, when it happens in isolated rural area the main authority of the locality the one in charge of doing this task. Is filled out following the guidelines of the World Health Organization established in the *International Statistical Classification of Diseases and Related Health Problems* (PAHO/WHO, 2019) to identify the specific cause of death and have international comparability.

Besides, the death certificate additionally captures more than 50 variables on the geographic space of residence and sociodemographic and contextual characteristics of the deceased as: entity and municipality of registry, entity, municipality and locality of habitual residence; entity, municipality and locality of occurrence of death; sex, age, occupation, schooling, conjugal status, among others (SSA, 2019).

The *International Statistical Classification of Diseases and Related Health Problems* (CIE) identifies in its tenth edition among the different causes of death those caused by *exposure to forces of nature* that are (PAHO, 2018):

- Exposure to excessive natural heat
- Exposure to excessive natural cold
- Exposure to sun rays
- Victim of lightning
- Victim of earthquake
- Victim of volcanic eruption
- Victim of avalanche, landslide and other earth movements
- Victim of a cataclysmic storm
- Victim of flood
- Exposure to other forces of nature, and the non-specified ones

The objective of this research is to know the current status and changes in mortality due to exposure to natural phenomena during the period 2000-2015, as well as to identify if there is a profile among people who died from these causes. To this end, the microdata of the death registry for the indicated period was used.

The data about the deaths by meteorological disasters are presented in the research in absolute numbers and in rates to highlight the risk that the population in Mexico faces, the rates are expressed per million of people and are calculated:

$$\text{TMDM} = \frac{\text{Number of deaths occurred during the period x per meteorological disaster}}{\text{Number of people exposed to the risk during the period}} \times 1{,}000{,}000 \quad (1)$$

The microdata of the mortality in Mexico of which the deaths by meteorological disaster were selected, where processed in the program STATA V.11, the graphics where elaborated in EXCEL and the maps in MapViewer.

3. Results

During the period 2000/2015 occurred in Mexico 4,177 deaths by meteorological disasters, being the year 2009 the cohort of time in which the lowest number of deaths was registered with 203 and the year 2004 with the highest with 324 deaths. Of the total of deaths little more than a third 1,424 where registered between the years 2010 and 2015. Analyzing the incidence in mortality from meteorological disasters in Mexico according to the year of occurrence, it can be perceived over the studied period a slight tendency of decrease (Figure 1), but the lethality of the extreme climate events keeps constant with a rate close to 2 deaths per million people annually in average, in the year 2015 the rate was of 2.1.

For specific cause of death according to the type of meteorological disaster occurred in the period of study (Figure 2), it stands out that most of the deaths by meteorological disasters were due to lightning (46.8%), followed by excessive cold (20.2%), heat stress (17.8%), avalanches or landslides (7.6%), storm (2.4%), flood (1.8%), exposition to sun rays (1.7%), earthquake (1.0%), volcanic eruption (0.1%) and others (0.7%).

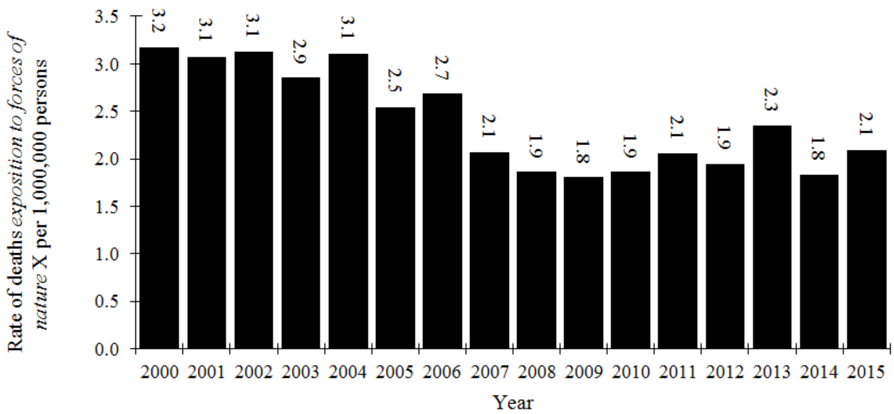

Figure 1. Rate of deaths by exposition to meteorological disasters in Mexico, during the years 2000 to 2015

Source: Own elaboration based on the microdata of death in Mexico, INEGI-SSA, 2000-2015.

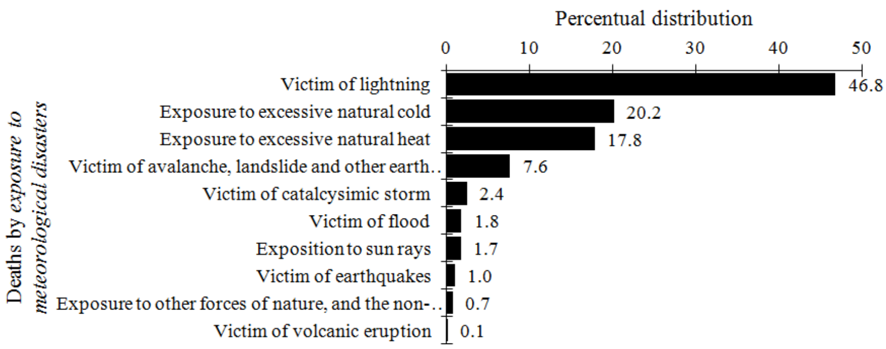

Figure 2. Percentual distribution of deaths per meteorological disasters in Mexico according to the cause, 2000 to 2015

Source: Own elaboration based on the microdata of death in Mexico, INEGI-SSA, 2000-2015.

The often catastrophic and highly destructive meteorological disasters such as hurricanes and earthquakes caused fewer deaths compared to other less catastrophic meteorological disasters such as lightning, exposure to extreme cold or heat stress.

In the evolution of deaths by specific cause and type of meteorological disaster, it is observed that each follows a different trend (Figure 3). Between 2000 and 2015, deaths by heat stress, avalanches, cataclysmic storms, floods and earthquakes have increased while deaths by cold waves and lightning have decreased.

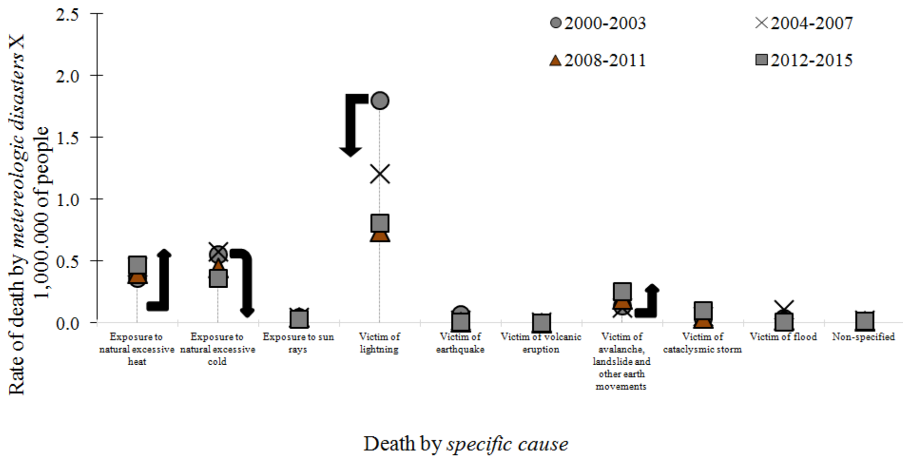

Figure 3. Mortality rates from meteorological disasters in Mexico by cause, in four cohorts of time during the period 2000-2015

Soucer: Own elaboration based on the microdata of deaths in Mexico, INEGI-SSA, 2000-2015.

According to geographic space of residence, the cumulative rate for meteorological disasters 2000-2015 presents variations (Figure 4). The states of Sonora (9.9 deaths per million), Chihuahua (7.5), Zacatecas (4.6), Guerrero (3.8), Michoacán (3.4), Nayarit (3.5), Oaxaca (3.6), San Luis Potosí (3.2) and Coahuila (3.1) are those that registered the highest rates, which were higher than those estimated worldwide by Goklany, in 2009, which was 3 deaths per million.

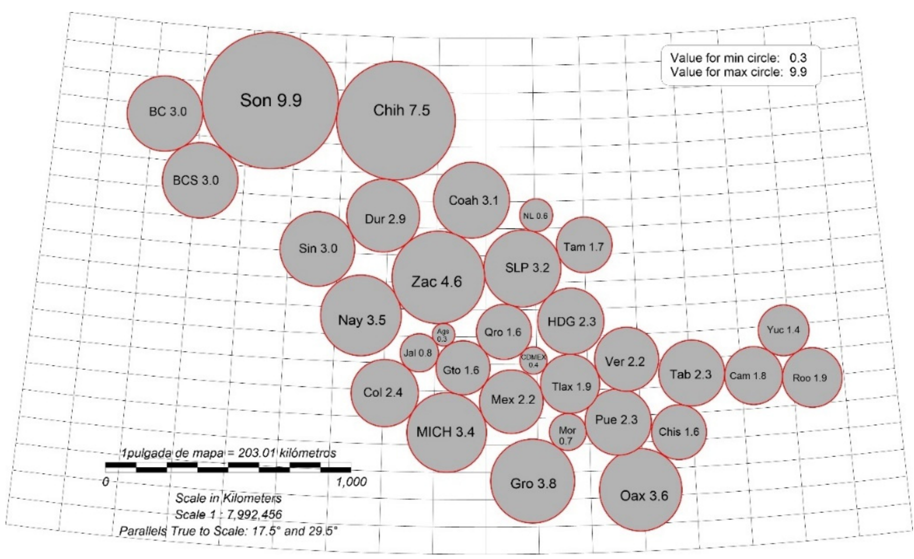

Figure 4. Accumulative rate of deaths by meteorological disasters in Mexico by entity of occurrence for the period of 2000-2015

Source: Own elaboration based in the microdata of deaths in Mexico, INEGI-SSA, 2000-2015.

The comparison of the percentual distribution of the deaths by type of meteorological disaster in five sizes of localities, showed differences in the incidence level (Figure 5). For example, the deaths by lightning strike have a bigger percentual weight in the localities of smaller size (less than 15,000 habitants), where more than 50% were concentrated, while in the metropolitan cities (localities of more than five hundred thousand habitants) only 8.5% of this type of deaths occurred. In general, the smaller the size of the locality of occurrence the larger the incidence of death by lightning.

The deaths by heath or cold stress have a bigger concentration in bigger localities, in the metropolitan cities (localities of more than five hundred thousand habitants) of the total of the deaths by exposition to nature phenomena, 41.8% were from extreme cold while 38.2% were from heat stress. While in the rural localities the deaths by extreme cold represented 15.5% and from heat stress 9.4% of the total, respectively.

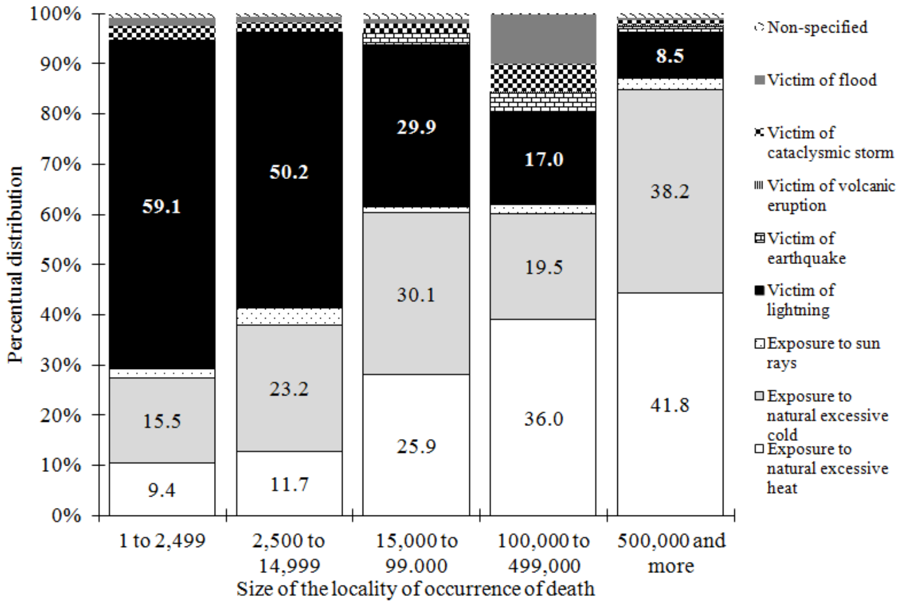

Figure 5. Percentual distribution of death by meteorological disasters in Mexico by size of the locality of occurrence for the period 2000-2015

Source: Own elaboration based on the microdata of deaths in Mexico, INEGI-SSA, 2000-2015.

While the deaths by exposition to sun rays do not follow a defined pattern, they occur in a similar proportion in all sizes of localities. On the other hand, deaths by storms, floods and earthquakes in bigger proportion occur in intermediate cities from 100 thousand to 499 thousand habitants.

Comparing between the sexes the total accumulated of deaths by meteorological disasters, 81.2% were men and 18.8% women. By size of locality of occurrence, the difference by sex is maintained in the five analyzed sizes (Figure 6).

According to the type of meteorological disaster, important differences are observed in the composition by sex (Figure 7), more men died due to cold waves (88.6%), heat stress (81.6%), lightning (80.6%), avalanche (80.5%) and solar rays (80.3%). While more women died by volcanic eruption (66.7%), flood (45.9%), earthquake (36.6%) and cataclysmic storm (35.0%). There is a clear relationship between the division of labor by sex and the risk of dying from a specific meteorological disaster.

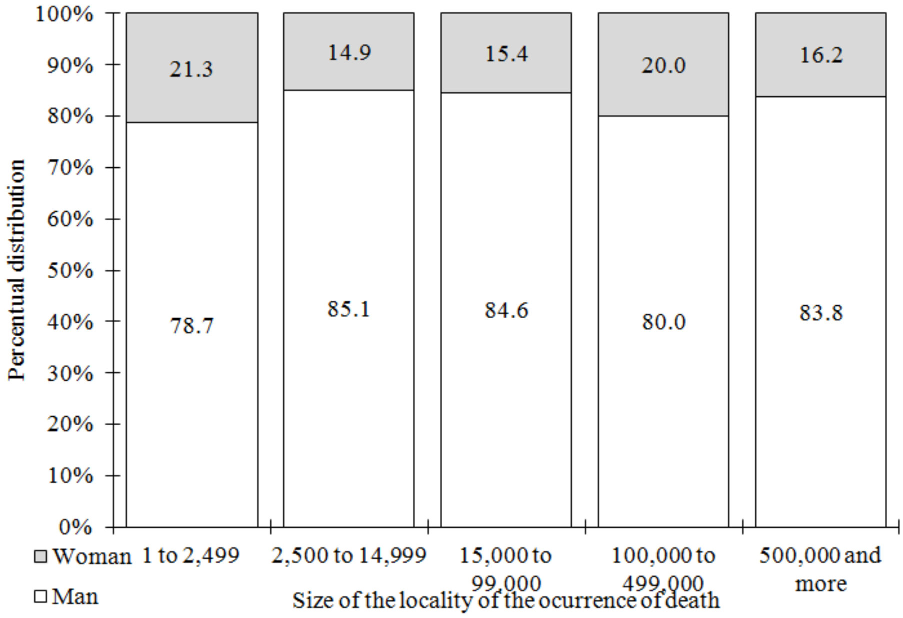

Figure 6. Percentual distribution of deaths by meteorological disasters in Mexico according to sex and size of locality of occurrence for the period 2000-2015

Source: Own elaboration based on the microdata of death in Mexico, INEGI-SSA, 2000-2015.

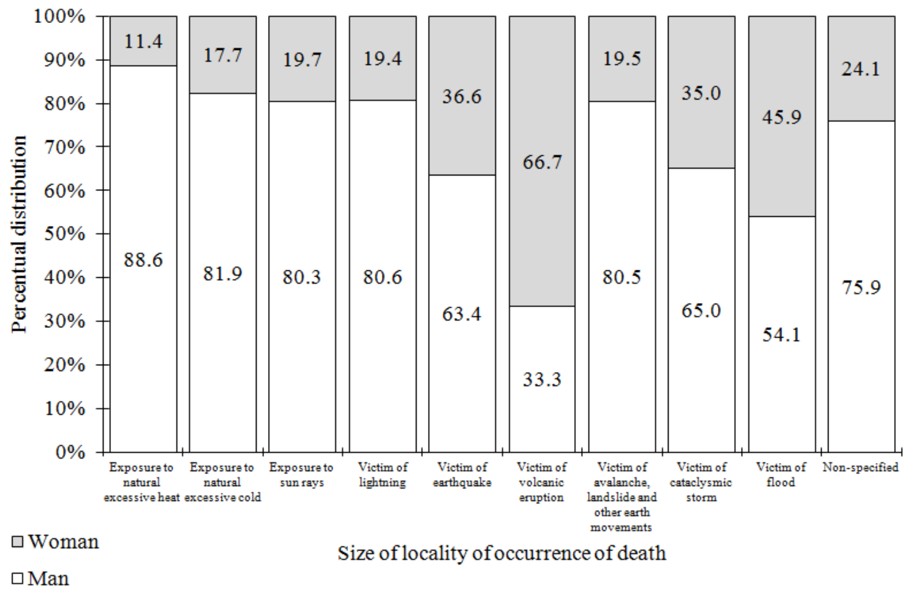

Figure 7. Percentual distribution of death by meteorological disasters in Mexico according to sex and type, 2000 to 2015

Source: Own elaboration based on the microdata of death in Mexico, INEGI-SSA, 2000-2015.

The victims of a meteorological disaster had at the time of their death an average of 40 years, differentiating by age and sex, men have a higher average age of 40.9 years compared to women of 38.4 years. The differences by sex are sharpened in the distribution of age according to percentiles, since in the first quartile (or the 25th percentile) women barely reach 15 years old and men 24 years, this shows that among women girls have an increased risk of dying from a meteorological disaster unlike men.

According to the type of meteorological disaster, differences in the average age were observed, being victims by volcanic eruption those of greater age at the time of death with an average of 78 years, followed by those who died by sunrays with an average of 53 years and extreme cold with an average of 52 years. Meanwhile, victims aged between 32 and 35 years old on average died from avalanche, lightning and storms (Table 1).

In the distribution by percentiles of Table 1, it stands out that the victims of floods and storm in comparison with the other meteorological disasters affects to a greater extent younger people, mainly boys and girls, in the first quartile the victims of these events barely reached the age of 11 and 14 years, respectively. In contrast, events such as volcanic eruption, excessive cold and earthquake affected mainly the elderly, in the third quartile (or 75th percentile) the victims of these disasters had an average of 83, 75 and 71 years.

Table 1. Percentage of ages of deaths by meteorological disasters in Mexico from specific causes for the period 2000-2015

Cause of death	Mean	Percentiles		
		25	50	75
Exposition to excessive natural heat	47.6	33.0	46.0	61.0
Exposition to excessive natural cold	52.0	35.0	54.0	75.0
Exposition to sun rays	53.4	36.5	53.0	71.5
Victim of lightning	34.2	18.0	31.0	48.0
Victim of earthquake	48.5	29.7	47.5	71.5
Victim of volcanic eruption	78.0	73.0	78.0	83.0
Victim of landslide, avalanche and other earth movements	32.7	19.0	30.5	44.0
Victim of cataclysmic storm	35.4	14.0	32.5	55.8
Victim of flood	40.3	11.0	36.0	67.3
Exposition to other forces of nature and the non-specified	37.9	15.5	33.0	55.5

Source: Own elaboration based on the microdata of death in Mexico, INEGI-SSA, 2000-2015.

In the pyramid of age and sex of deaths by meteorological disasters for the period 2000-2015, the differences between men and women that give it an atypical shape stand out. Thus, the deaths of men are concentrated in the productive ages and in the group of adults 65 years and older, whereas among women deaths remain at a similar level in all age groups, to have an exponential growth in the cohort 65 years and older (Figure 8).

The differences in the composition by sex and age of the population that has been the victim of a meteorological disaster change according to the type of disaster they were exposed to, in figure 8 the pyramids are shown for four types of meteorological disasters: heat stress, extreme cold, lightning and avalanche, which are the ones with the biggest numerical relevance.

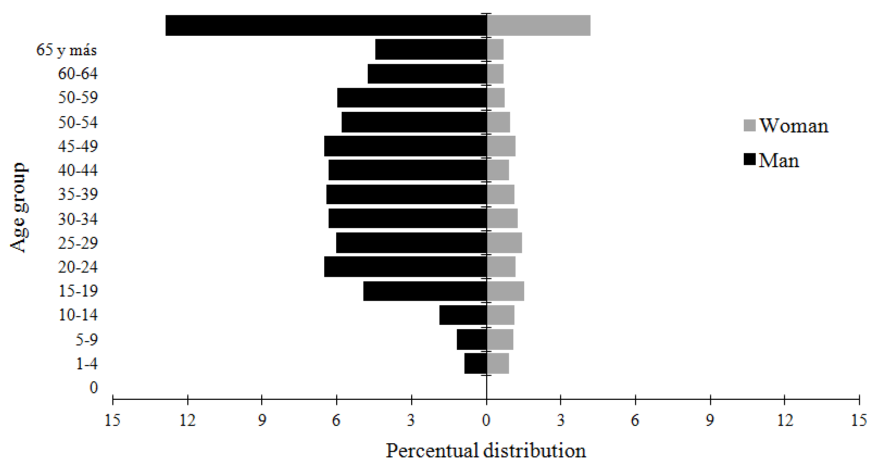

Figure 8. Percentual distribution of by meteorological disasters according to age groups and sex for the period 2000-2015

Source: Own elaboration based on microdata of death in Mexico, INEGI-SSA, 2000-2015.

For the case of extreme heat, in the men the deaths centered in the cohorts of ages from 20 to 54 years old and in the 65 years and older, while in the women were in the 65 years and older. Meanwhile, the victims of cold stress in the pyramid the deaths were centered in the men of 45 to 49 years of age and the older than 65 years, between the women the age cohort more affected by this type of event were the older women of 65 years and older and the children of 0 to 5 years of age (Figure 9).

Lightning deaths in men are concentrated in the age cohort of 10 to 19 years and in women in the group of 10 to 14 years. While in deaths by avalanches the most affected were men from the age cohorts of 15 to 39 years old and women from two cohorts, girls from 1 to 9 years old and young women from 20 to 29 years old (Figure 9).

The risk of dying due to a meteorological disaster is different according to the level of education, the 43% of people that died for this cause didn't have any level of instruction, 19.5% had studied some grade of primary education; while, 15.7% of the victims had a level of basic education (primary and secondary school), 4.8% intermediate studies (high school) and only 10.3% had university studies (Figure 9).

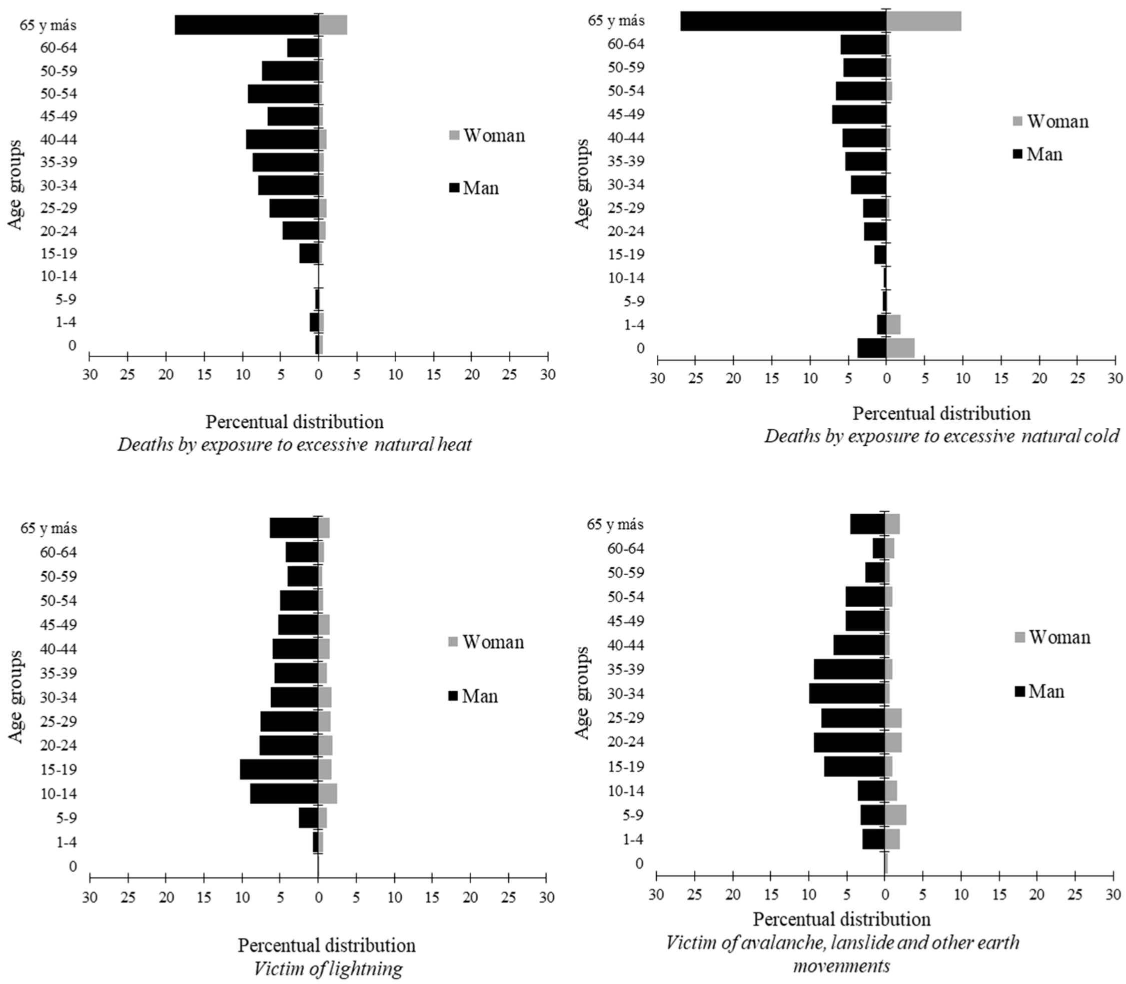

Figure 9. Percentual distribution of death due to meteorological disasters in Mexico by age group, sex and specific cause, for the period 2000-2015

Source: Own elaboration based on the microdata of death in Mexico, 2000-2015.

Comparing by sex, the women victims of some meteorological disaster had a lower level of education compared to men. Of the total of female victims 41.5% didn't have any level of instruction proportion that between men decreases to 33.9%. The women that died due to a meteorological disaster have a double condition of vulnerability, being women and analphabet (Figure 10).

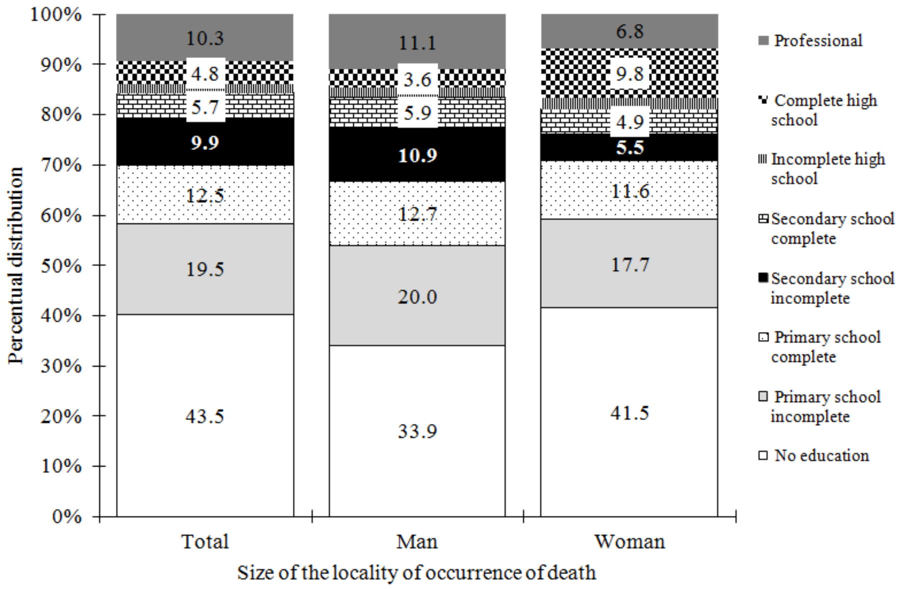

Figure 10. Percentual distribution of by meteorological disasters in Mexico, by level of education and sex for the period 2000-2015

Source: Own elaboration based on the microdata of death in Mexico, INEGI-SSA, 2000-2015.

Differencing the level of education of the victims by specific cause of mortality of the victims of meteorological disaster, it was observed that the educational level has a differential effect in the risk of dying by a type of specific meteorological disaster, for example, a bigger proportion of people without education died due to volcanic eruption, sun rays and cold stress, in counterpart, having a greater education is more probable being victim of an earthquake, excessive cold and heat stress (Table 2). Is confirmed that the lack of formal education can contribute to increasing the risk before extreme climate events.

Regarding the occupation of the people that were victims of a meteorological disaster 29.7% didn't have a job. Between those that had an economic activity, stands out that 44.5% worked in agricultural, livestock, forestry, hunting and fishing activities, 9.1% worked in the transformation industry (Note 2) and 3.2% were lower level administrative workers. Overall, they carry out economic activities that require a low level of qualifications and have a low salary, is corroborated that poor people have a higher exposition to the risk of dying due to a meteorological disaster (Table 3).

Table 2. Percentual distribution of death due to meteorological disasters in Mexico, by level of education and specific cause for the period 2000-2015

	No education	Basic Education	Middle Education	Higher Education
Exposition to excessive natural heat	30.6	46.2	7.1	16.1
Exposition to excessive natural cold	41.8	29.9	9.9	18.5
Exposition to sun rays	45.5	44	3	7.6
Victim of lightning	35.5	55	4.3	5.3
Victim of earthquake	33.3	33.4	12.9	20.5
Victim of volcanic eruption	66.7	33.3	0.0	0.0
Victim of landslide, avalanche and other earth movements	27.4	55.1	9.6	7.9
Victim of cataclysmic storm	36.3	44	13.2	6.6
Victim of flood	31.5	43.9	13.7	11
Exposition to other forces of nature and the non-specified	21.4	60.7	7.2	10.7

Source: Own elaboration based on the microdata of death in Mexico, INEGI-SSA, 2000-2015.

Table 3. Percentual distribution of death due to meteorological disasters in Mexico according to occupation for the period2000-2015

Occupation	Percentage
Didn't work	29.7
Professionals and technicians	1.1
Workers in agricultural, livestock, forestry, hunting and fishing activities	44.5
Education workers	0.5
Art, sports and entertainment workers	0.2
Officials and Managers	0.1
Control personnel in the industrial production process	0.1
Workers in the transformation industry	9.1
Operators of fixed machinery	0.8
Helpers in the process of industrial and artisan production	3.2
Drivers of mobile machinery and means of transport	1.1
Lower level administrative workers	3.2
Merchants, employees of commerce and sales agents	1.8
Street vendors	0.4
Workers in personal services in establishments	0.8
Workers in domestic services	0.1
Workers in the armed forces, protection and surveillance	1.2
Workers in elementary and support activities	2.2
Total	100.0

Source: Own elaboration based on the microdata of death in Mexico, INEGI-SSA, 2000-2015.

In the case of the people that worked in agricultural, livestock, forestry, hunting and fishing activities mostly 64.0% died by lightning 13.8% by extreme cold and 13.2% by excessive heat. The data shows that the agricultural workers could have less knowledge and capacity to adapt to the meteorological non-catastrophic disasters, thus the information about how to confront the meteorological conditions of the electric storms and the temperature must be prioritized for the workers that develop agricultural activities.

4. Discussion

The results of the present study show that in Mexico the mortality from meteorological disasters has remained constant during the period 2000-2015, which is why an unacceptably high lethality of extreme weather events persists with a rate close to 2 deaths per million people annual average, since most of those deaths could have been prevented. Rates for Mexico present a trend different from that suggested by Goklany (2009), who points out a clear downward trend in the world of mortality caused by meteorological disasters.

The study found that the majority of deaths from weather disasters were due to lightning (46.8%), the lethality of lightning is generally underestimated, although a large number of deaths are reported per year (Singh and Singh, 2015). It was also corroborated that it is mainly men who are at higher risk of dying from this cause compared to women. In addition, it is the people who carry out agricultural activities who have a higher risk of dying from this cause, these results agree with two studies conducted in India (Singh and Singh, 2015; Mahapatra, Walia, & Saggurti, 2018).

In addition to lightning deaths, excessive cold (20.2%) and heat stress (17.8%) were the main causes of death, this is especially relevant if we consider that climate change projections for Mexico show that throughout In the next century, the heat and cold waves will be more frequent, intense and last longer, even in regions where they are not currently characterized by heat waves or cold, so programs need to be developed to reduce lethality and co-morbidity of these meteorological disasters.

The results corroborated that there is a heterogeneous geographical vulnerability, the states of Sonora, Chihuahua, Zacatecas, Guerrero, Michoacán, Nayarit, Oaxaca, San Luis Potosí and Coahuila recorded the highest rates, which were higher than those estimated at the national level world-wide by Goklany, in 2009, which was 3 deaths per million, so the actions of the State for the management of risks due to meteorological disasters should be focused.

It is verified that the lethality of the disasters is produced not only by the exposure to a certain threat, but also, due to the accumulated vulnerability in which certain populations are found, this result coincides with others carried out in different countries (Michelozzi et al., 2005; Zagheni et al., 2015; Myung & Jang, 2011; Mahapatra, Walia,

& Saggurti, 2018), therefore, the impacts of natural disasters are not evenly distributed among population subgroups. This research found that men of productive ages and older adults, as well as women in particular, girls under nine years old and older adults are at greater risk of dying from a meteorological disaster, so prevention programs must specifically be targeting these populations, which would reduce the impact on mortality from weather disasters.

This study found that there is a pattern between the type of meteorological disaster and the size of the locality of residence, while lightning deaths are concentrated in rural locations, deaths due to cold or heat hits occur in a greater proportion in metropolitan cities, this could be relevant for the formulation of intervention programs to reduce mortality from disasters.

The results of this investigation corroborated that there is a clear division of labor by sex and risk of dying according to the type of meteorological disaster. Women are at greater risk of dying from catastrophic, highly destructive meteorological disasters, due to infrastructural collapse, particularly in housing. Gasman (2019) points out that: "Mexico City has witnessed the vulnerability of women and girls to disaster risks, such as the one that occurred on September 19, 2017, where official figures showed that, of a total of 228 people who died and were later rescued from buildings collapsed in the City, 138 were women; that is, two women for every man "(p. 1).

While men had a higher risk of dying from a non-catastrophic or less destructive weather disaster that regularly occurs in open spaces. Men have a greater labor participation in activities such as agriculture, construction or other outdoor activities, this increases their exposure to meteorological disasters such as lightning, avalanches and solar rays. These results agree with the findings pointed out by de Singh and Singh (2015). Men die more than women from weather disasters due to imprudence, believing that they do not need to take precautions are more likely to take risks without assessing the severity of the situation they face as cold or extreme heat.

The results of the characteristics of people killed by a meteorological disaster confirmed that the lack of formal education can contribute to increase the risk in certain extreme climatic events and that it is the people who carry out economic activities that require a low level of qualification and salary, that is, poor people who have a greater exposure to the risk of dying from a meteorological disaster, these results coincide with those found in studies on heat wave mortality (Michelozzi et al., 2005; Díaz, Castro, & Aranda, 2014).

This study found that agricultural workers have a higher risk of dying from a meteorological disaster compared to other workers, we believe that agricultural workers may have less knowledge and ability to adapt to non-catastrophic weather disasters, therefore, information on how to deal with the weather conditions of thunderstorms and temperature should be prioritized for workers who develop agricultural activities.

An advantage of this study is that we analyze the causes of death of all types of meteorological disasters in detail, unlike previous studies (Rojas-Rodríguez & Hurtado-Díaz, 2006; Díaz, Castro, & Aranda, 2014). We not only analyze the causes of death but also the characteristics of the people, which are fundamental to identify who is vulnerable to what danger is fundamental in the intervention efforts to reduce vulnerability.

A limitation of this study is that we do not have information on social or environmental variables that could be important to identify the population at risk, such as the disability, ethnic or health condition, nor do we have information on the level of preparedness for disasters, the rate of victims, the density of injured per unit area or the perception of risk that people have.

In the future, an information system should be implemented to measure the degree of vulnerability in each place continuously and systematically, with the objective of reducing the risk of disasters and increasing the security and resilience of the communities. This strategy is part of Goal 13: Climate Action of the Sustainable Development Goals.

5. Conclusion

In this investigation it has been demonstrated that the impact of the natural disasters is not evenly distributed between the subgroups of population, this is because the vulnerability is multidimensional and dynamic. Identifying who is vulnerable to which hazard is fundamental in the efforts of intervention to reduce the vulnerability.

The mortality due to natural disasters is unacceptably high, most of these deaths could have been avoided. The lethality of the disasters occurs not only because of the exposition to certain hazards, but also because of the accumulated vulnerability in which certain populations are in.

Considering the results of the research, the prevention programs must be specifically aimed to men in productive ages and elderly, to the women the girls younger than nine years and elder women, which would reduce the impact of mortality due to natural disasters.

It is expected that climate change in Mexico will cause throughout the next century that heat and cold waves will be more frequent and intense, this is important because deaths from cold and heat were the second and third most important because of its incidence, so it is necessary to develop programs especially in urban areas where most deaths occur due to this cause to reduce the lethality of these meteorological disasters.

Notes

Note 1. Vulnerability indexes have been able to demonstrate that it is possible to have a unit of analysis over a period.

Note 2. The workers considered in this group do activities in a workshop, commercial establishment, mines or quarries, construction sites, on public spaces, in their own home or the home of their clients.

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Conflict of interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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