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## EXPOSURE TO EARTHQUAKES — DISTRIBUTION AND CHANGE OF THE WORLD'S POPULATION WITH REGARD TO DISPOSITION OF SEISMIC ACTIVITIES

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**Abstract:** Earthquake effects can be distinctly different in two different countries even if the earthquake has the same level of intensity. Loss and damage caused by the earthquake will be much less in developed countries than in developing countries. Due to its inability to prevent and cope with disasters developing countries are in the focus in this article. This paper presents an approach for detecting the most and the least vulnerable countries of the world and the distribution of their population within different earthquake intensity zones. There is also a summary of the change in world population during the 25-year period (1990–2015), within continents and earthquake intensity zones as well as a comparison between continents. The population growth is unevenly distributed and highest in the zone with probable maximum intensity VIII. In relation to the World population by earthquake intensity zones, the developing countries have the lowest share of its population among the zone with most destructive earthquakes.

**Keywords:** earthquake intensity zones, population, vulnerability, developing countries

### Introduction

Although there are geographical explanations of distribution of the world's population and disposition of seismic activities, the both are unevenly distributed. They are concentrated zonally and these zones often overlap. Seismic vulnerability, besides on earthquake's own strength, depends on population density and country's level of development. Developing countries are the most vulnerable in every way, and the poor and marginalized groups in these countries are at most risk.

According to the terminology of the United Nations (UN, 2012), economies in transition and developing economies represent countries with a low or medium national income per capita, with a relatively underdeveloped economic structure and a relatively small share in world production and trade. Developing countries

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are highly vulnerable to natural disasters. Accident can easily become catastrophe and wipe out decades of development in just a few minutes. The regulations on construction are less respected in these countries and they also have lower control mechanisms. The coordination in emergency situations is often weak. Compared to developed countries, the level of corruption is high. Religious and ethnic discriminations are very common. Supplies are not evenly and efficiently distributed among all social groups and thus all of these conditions can only worsen the consequences of natural disasters.

In aid workers' reports there is constant emphasis on need for adequate help and there are often claims that widespread corruption and many other irregularities endanger public distribution of humanitarian aid. After the earthquake in Guatemala in 1972, "assistance was directed mainly to middle-class people while the poor were largely ignored" (Özerdem, 2006). In Gujarat, India, after the earthquake in 2001 "foreign aid workers admit they fear that Dalits and Muslims may lose out" (Harding, 2001).

Susceptibility to disasters is different regarding the social status. Marginalized groups and the poor have always been at most risk from natural disasters. They are forced to live in risky areas, especially in the growing urbanized world. Women are also at greater risk due to natural disasters, and that includes the burden that brings home repairing and provision of resources for life after such events. Many reports, including the ones from Asian tsunami in 2004, have shown that women and other dependents suffered much higher mortality compared with adult men (Oxfam, 2005). Reports indicate that in earthquakes, in the greatest danger are people older than 60 years, children and the chronically ill, as opposed to other groups of the population (Naghii, 2005).

### **Materials and methods**

Zones of probable maximum earthquake intensity, used in this study, are a spatial data set made by United Nations Environment Programme and Global Resources Information database (UNEP/GRID). Zones are based on expectations of earthquake intensity for a period of 50 years and they match Modified Mercalli Scale from 1956. Besides this 12-value scale there are only 5 intensity zones with probable maximum intensity: 1. V and below, 2. VI, 3. VII, 4. VIII and 5. IX and above. As it is stated in the description, "the intensity describes exclusively the effects of an earthquake on the surface of the earth and integrates numerous parameters (such as ground acceleration, duration of an earthquake, subsoil effects)" (UNEP, 2001). The data are built on World Map of

Natural Hazards published by Münchener Rückversicherungs-Gesellschaft (Munich Re, 2011) in 1988.

The third edition of Gridded Population of the World (GPWv3) is used for observing the distribution of the population and its number (Center for International Earth Science Information Network [CIESIN], 2005). These data represent the estimation of human population for the years 1990, 1995, and 2000 and projection for the years 2005, 2010, and 2015. This spatial database is produced by the United Nations Food and Agriculture Programme (FAO), the Columbia University Center for International Earth Science Information Network (CIESIN) and Centro Internacional de Agricultura Tropical (CIAT) in order to provide spatial relations of human population and the environment all over the world. Only a part of database is used in this research – Centroids. These point data consist of 399,781 points which represent the centers of administrative units with population of it as attributes. Administrative units are of various levels and can differ largely. For example, within the territory of Slovenia points represent centers of municipalities. Some of them are with population less than 100. On the other hand, Serbia is represented with only 3 points located in the center of autonomous provinces and Central Serbia. Central Serbia alone has a population of more than 5,000,000.

Analysis of zones of probable maximum earthquake intensity and population growth rate is done in ArcGIS in order to determine regularities in increase and decrease of world's population depending on earthquake intensity zones and detect the areas that will be most endangered in the future. *Spatial Join* tool within this software is used for combining shapefiles and transferring their attributes based on their spatial relationship. Attribute data from two polygon data files which represent zones of probable maximum earthquake intensity and boundaries for the continents are transferred to point data, centroids which already include information about human population. Before combining those files there was a need to adjust their cartographic projection and prime meridian. Boundaries of continents and countries in those shapefiles are highly simplified and there was a lack of some islands. In that situation some of centroids fall outside of polygon data. In order to minimize the error, option *Closest* within *Spatial Join* tool was used and the information of nearest continent and zone of probable maximum earthquake intensity are transferred to centroids.

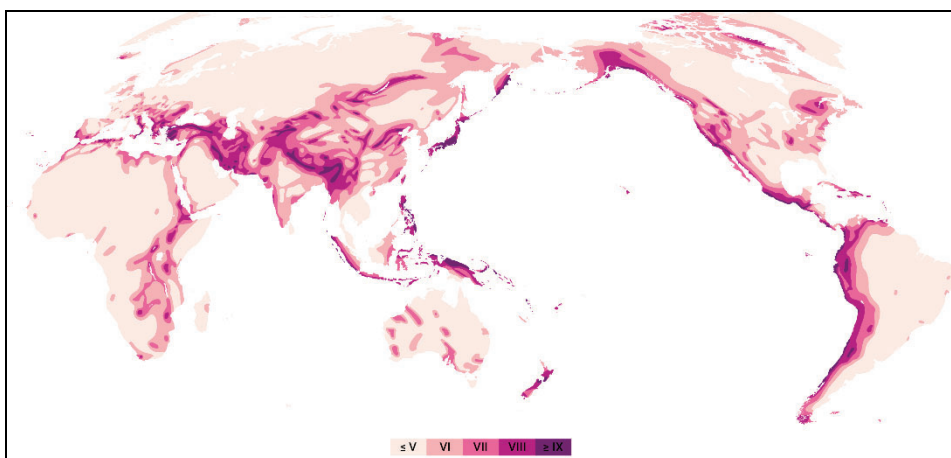


Figure 1. Global Earthquake Intensity Zones (Author Djordjević M., based on spatial data from UNEP, 2001)

Colour combinations used for a map (Figure 1) are obtained from <http://colorbrewer2.org> (Brewer, 2013) in order to be readable by colour vision impaired persons and thus be able to understand the message the map is trying to send. Mollweide projection, pseudocylindrical and equivalent map projections were chosen to maintain equal-area properties. Due to tectonic plate disposition Greenwich was not used as a central meridian. In this way Pacific-centred map was used to add accent to the Pacific Ring of Fire.

## Results and discussion

### *Population growth rate in the world and its distribution within continents in relation to the vulnerability to earthquakes*

The number of people living in the IX category or higher on Modified Mercalli earthquake intensity scale is estimated to be over 270,000,000 people in 2015, or 3.8% of the world population (Table 1). Population is growing constantly in this zone but at the same time there is a regular decline in share of total world population. In all zones the number of inhabitants is growing, but the percentage share of world population is declining except in zone VIII. The greatest population growth in 25-year period of 156% is in the zone VIII.

Table 1. Population growth rate in the world from 1990 to 2015 by zones of the maximum intensity of earthquake and their share in the total population of the world

Year	Modified Mercalli earthquake intensity									
	≤ V		VI		VII		VIII		≥ IX	
	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%
1990	1,542,395	29.3	1,631,466	31.0	1,187,275	22.6	677,836	12.9	215,413	4.1
1995	1,646,869	29.1	1,761,562	31.1	1,287,087	22.7	737,226	13.0	228,626	4.0
2000	1,746,852	28.8	1,884,182	31.1	1,386,523	22.9	797,314	13.2	241,517	4.0
2005	1,846,252	28.7	1,998,809	31.0	1,481,422	23.0	860,763	13.4	253,453	3.9
2010	1,946,143	28.5	2,105,769	30.8	1,572,280	23.0	936,779	13.7	264,316	3.9
2015	2,039,979	28.3	2,187,342	30.3	1,648,816	22.9	1,057,983	14.7	272,713	3.8

<sup>(1)</sup> Population in thousands

From geographical point of view, the most vulnerable parts of Europe to earthquakes are those closest to the African continent and Asia Minor. A percentage share of the European population living in the safest zone ≤ V category is the second highest, just after Australian (Table 2). There live about 60% of the population. Only 16% of the population or about 105,000,000 live in zones of the VII category and higher. As the countries of Europe have negative or low natural increase rate, changes in population number over a time and within zones are negligible.

Table 2. Population growth rate in Europe from 1990 to 2015 by zones of the maximum intensity of earthquake and their share in the total population of the continent

Year	Modified Mercalli earthquake intensity									
	≤ V		VI		VII		VIII		≥ IX	
	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%
1990	411,537	60.7	159,393	23.5	62,018	9.1	40,396	6.0	4,384	0.6
1995	415,063	60.6	161,270	23.5	62,991	9.2	40,748	5.9	4,387	0.6
2000	412,867	60.3	162,894	23.8	63,130	9.2	40,846	6.0	4,369	0.6
2005	408,075	60.0	163,060	24.0	63,122	9.3	40,933	6.0	4,310	0.6
2010	403,204	59.8	162,387	24.1	62,837	9.3	40,791	6.1	4,222	0.6
2015	398,146	59.7	161,220	24.2	62,346	9.3	40,569	6.1	4,114	0.6

<sup>(1)</sup> Population in thousands

The most populated continent ranks first in the increase in population, and second in the percentage of increase. In the 25-year period the population increased by 37%, with the largest growth in zones VII and VIII which is clearly reflected in the global level (Table 3). In zones of the categories IX and higher in 2015 lived about 5% of the population of Asia, or over 200,000,000 which is 80% of all people in the world who inhabit this zone of highest earthquake intensity. 95% of the Asian population lives in developing countries. The only developed countries in Asia are Japan, Singapore, Hong Kong, Taiwan, South Korea and Israel.

Table 3. Population growth rate in Asia from 1990 to 2015 by zones of the maximum intensity of earthquake and their share in the total population of the continent

Year	Modified Mercalli earthquake intensity									
	≤ V		VI		VII		VIII		≥ IX	
	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%
1990	550,595	17.2	1,160,605	36.2	847,268	26.4	475,065	14.8	175,118	5.5
1995	589,090	17.0	1,255,009	36.2	920,585	26.5	518,187	14.9	185,188	5.3
2000	625,850	16.8	1,341,834	36.1	991,580	26.7	562,439	15.1	194,868	5.2
2005	658,875	16.7	1,423,311	36.0	1,058,513	26.8	609,258	15.4	203,637	5.2
2010	688,294	16.4	1,498,016	35.8	1,120,993	26.8	668,165	16.0	211,209	5.0
2015	707,430	16.0	1,546,201	35.0	1,169,084	26.5	772,126	17.5	216,433	4.9

<sup>(1)</sup> Population in thousands

Throughout the African continent there are areas with high seismic and volcanic activities. The greatest number of volcanoes and earthquakes is concentrated along The Great Rift Valley which extends along the eastern part of the continent. The African plate is moving towards Eurasian plate and the Mediterranean subduction zone causes earthquakes and volcanoes, which can generate tsunamis and affect the northern coast of Africa.

All African countries are developing countries. In the area of The Great Rift Valley are the least developed countries of Africa, which makes this area even more vulnerable. For the last 25 years, the population in Africa increased by 80%, which is a record, compared to other continents (Table 4). The only decline in population is recorded in the zone of the categories IX and higher. Population in this zone is now equal to Oceania’s population (without Australia) in the same zone. Together they have fewer residents in this zone than any other continent in the same one, with exception of Australia where the maximum category is VII. The highest population growth was recorded in the safest zone that contains 48.5% of the population, where the population has almost doubled in 25 years, and where there is no indication that growth will decrease.

Table 4. Population growth rate in Africa from 1990 to 2015 by zones of the maximum intensity of earthquake and their share in the total population of the continent

Year	Modified Mercalli earthquake intensity									
	≤ V		VI		VII		VIII		≥ IX	
	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%
1990	283,141	45.6	174,762	28.1	130,017	20.9	31,547	5.1	1,169	0.2
1995	324,644	46.0	198,858	28.2	144,180	20.4	35,771	5.1	1,175	0.2
2000	369,042	46.4	223,114	28.0	161,355	20.3	40,047	5.0	1,169	0.1
2005	420,653	47.1	247,219	27.7	178,725	20.0	44,923	5.0	1,166	0.1
2010	477,483	47.8	272,286	27.3	196,940	19.7	49,950	5.0	1,154	0.1
2015	539,267	48.5	299,123	26.9	215,876	19.4	55,312	5.0	1,137	0.1

<sup>(1)</sup> Population in thousands

The North American continent is characterized by localized volcanic activity and earthquakes. Collision between the North American plate and the Pacific plate caused a complex geological structure along the Pacific coast. In North America, the greatest part of the seismic activity is concentrated in California, where the San Andreas Fault, which lies along the coast, is associated with a number of strong earthquakes.

The only two developed countries in North America are the United States of America and Canada, and currently there live 80% of the population of North America. Half of the population of North America lives in the zones that are up to the category VI, and half in the zones of the category higher than VII (Table 5). This is the continent with the most regular distribution in these 5 categories. The growth of the population in all zones is noted, and the largest rise of 43.8% and 57.6% in the 25-year period is in the zone of the categories VIII and IX and higher, respectively. The effects of 1989 Loma Prieta's earthquake (California) with intensity of VIII in the most part and even IX in some parts (Bolt, 2005) are one of the most used facts in describing the difference in earthquake losses in developed and developing countries. During this one, 63 people are killed (Haynes et al., 1992). In similar intensity earthquakes, one in Armenia in 1988, more than 25,000 people were killed (Gates & Ritchie, 2007) and in Marmara earthquake in Turkey in 1999 more than 17,000 people were killed (Özerdem & Barakat, 2000).

Table 5. Population growth rate in North America from 1990 to 2015 by zones of the maximum intensity of earthquake and their share in the total population of the continent

Year	Modified Mercalli earthquake intensity									
	≤ V		VI		VII		VIII		≥ IX	
	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%
1990	110,491	25.8	109,448	25.5	113,685	26.5	78,352	18.3	16,093	3.8
1995	117,447	25.6	116,288	25.4	121,265	26.5	84,885	18.5	17,695	3.9
2000	125,095	25.6	123,299	25.3	128,521	26.3	91,264	18.7	19,411	4.0
2005	131,541	25.5	129,182	25.0	135,277	26.2	97,984	19.0	21,204	4.1
2010	137,362	25.3	133,998	24.7	141,872	26.2	105,330	19.4	23,271	4.3
2015	143,168	25.2	138,671	24.4	148,101	26.0	112,695	19.8	25,357	4.5

<sup>(1)</sup> Population in thousands

In South America, currently 60% of the population lives in the zone of the category V and lower (Table 6). Second most populous zone is the one of category VIII. Here, as in North America, population is growing in all zones, and also the most vulnerable is coastal area of the Pacific Ocean as a part of the Ring of Fire. All countries are developing countries.

Table 6. Population growth rate in South America from 1990 to 2015 by zones of the maximum intensity of earthquake and their share in the total population of the continent

Year	Modified Mercalli earthquake intensity									
	≤ V		VI		VII		VIII		≥ IX	
	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%
1990	174,175	59.0	22,342	7.6	31,102	10.5	49,630	16.8	17,752	6.0
1995	187,230	58.4	24,910	7.8	34,638	10.8	54,551	17.0	19,223	6.0
2000	199,757	57.8	27,529	8.0	38,301	11.1	59,419	17.2	20,691	6.0
2005	212,067	57.2	30,218	8.2	41,954	11.3	64,144	17.3	22,083	6.0
2010	223,988	56.7	32,963	8.3	45,623	11.6	68,797	17.4	23,366	5.9
2015	235,403	56.3	35,713	8.5	49,221	11.8	73,313	17.5	24,540	5.9

<sup>(1)</sup> Population in thousands

Unlike neighbouring New Zealand, any specific seismic activity in Australia is not noted in recent times, although several strong earthquakes hit the continent in the past. The northern part of the Australian Plate collides with the Eurasian Plate along Indonesia. At this spot subductive zone is formed below Indonesia, which produces earthquakes and volcanoes. While there are currently no active volcanoes in Australia, volcanism in the relatively near geological past has been very active. This activity is explained by the movement of Australia through the “hotspot”. Unlike Hawaii, where there is only one point of volcanic activity, volcanism in Australia is broken to multiple points which are located around the east coast of Australia.

Table 7. Population growth rate in Australia from 1990 to 2015 by zones of the maximum intensity of earthquake and their share in the total population of the continent

Year	Modified Mercalli earthquake intensity									
	≤ V		VI		VII		VIII		≥ IX	
	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%
1990	11,705	69.3	3,588	21.3	1,593	9.4	0	0.0	0	0.0
1995	12,580	69.6	3,848	21.3	1,642	9.1	0	0.0	0	0.0
2000	13,358	69.8	4,083	21.3	1,694	8.9	0	0.0	0	0.0
2005	14,074	70.0	4,300	21.4	1,734	8.6	0	0.0	0	0.0
2010	14,756	70.2	4,504	21.4	1,767	8.4	0	0.0	0	0.0
2015	15,415	70.4	4,701	21.5	1,793	8.2	0	0.0	0	0.0

<sup>(1)</sup> Population in thousands

Australia is a highly developed country and has the privilege to be the only continent that does not have zones VIII and IX and higher (Table 7). In other three zones population growth is present. In the zone of the category V or lower live 70% of the population, and therefore this is the safest continent regarding the risk of earthquakes.



Table 8. Population growth rate in Oceania from 1990 to 2015 by zones of the maximum intensity of earthquake and their share in the total population of the continent

Year	Modified Mercalli earthquake intensity									
	≤ V		VI		VII		VIII		≥ IX	
	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%
1990	751	10.1	1,328	17.9	1,592	21.5	2,846	38.4	897	12.1
1995	816	10.2	1,380	17.2	1,787	22.3	3,083	38.4	958	11.9
2000	884	10.3	1,428	16.7	1,943	22.7	3,299	38.5	1,009	11.8
2005	967	10.6	1,519	16.6	2,096	22.9	3,520	38.5	1,053	11.5
2010	1,056	10.8	1,615	16.6	2,248	23.0	3,745	38.4	1,094	11.2
2015	1,149	11.1	1,713	16.5	2,395	23.1	3,969	38.3	1,132	10.9

<sup>(1)</sup> Population in thousands

Oceania (without Australia) records a population growth of 40% (Table 8). Apart from New Zealand, which has about half of the population, all other countries are developing countries. Almost all of them are affected by strong earthquakes and half of the population lives in the zones of the category VIII and IX and higher. In this region, only 11% of the population lives in the zone of the category V or lower, which is the lowest percentage compared to other continents.

*Population growth rate within continents and within developing countries in relation to the vulnerability to earthquakes*

In developing countries in Europe, a bit less than a 1,000,000 people live in the zone of the category IX and higher, the most tectonically active one, and this places this continent in the last place by the number of threatened people in developing countries. It is followed by Oceania and Africa. Among developing countries in Europe, the Balkan countries, Romania, Russia and Ukraine are threatened (Table 9). In percentages, the population of Macedonia is the most vulnerable because 69% of the population live in zones VIII and IX and higher. In the tectonically calmest zone of the category V or lower live 70% of the population in developing countries, and Europe is the first in the world. Belarus, Lithuania and Latvia are entirely in the zone of the category V. In Poland 95% of the population live in the zone of the category V or lower, and in the European part of Russia more than 87%.

Table 9. Vulnerability of the population in the countries in Europe for 2015 in relation to the zone of the maximum possible intensity of earthquakes

Europe											
Country	Modified Mercalli earthquake intensity										Total popul.
	≤ V		VI		VII		VIII		≥ IX		
	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	
Macedonia					354	17	1,078	52	643	31	2,075
Bulgaria <sup>(2)</sup>			907	13	3,110	46	2,564	38	235	3	6,816
Albania					9	0	3,381	98	48	1	3,438
Romania <sup>(2)</sup>	2,768	13	5,363	25	6,895	32	6,410	30			21,436
Serbia					4,676	46	5,502	54			10,178
Russia	84,893	88	7,960	8	3,207	3	681	1			96,741
Croatia <sup>(2)</sup>			776	17	3,495	76	351	8			4,622
Ukraine	35,999	83	6,571	15	662	2	103	0			43,335
Montenegro					712	100					712
Bosnia and Herz.			4,279	100							4,279
Poland <sup>(2)</sup>	36,217	95	1,812	5							38,029
Belarus	9,664	100									9,664
Lithuania <sup>(2)</sup>	3,538	100									3,538
Latvia <sup>(2)</sup>	2,225	100									2,225
Kazakhstan	35	100									35
Total	175,339	71	27,668	11	23,120	9	20,070	8	926	0	247,123

<sup>(1)</sup> Population in thousands<sup>(2)</sup> Included in research even being EU member states

Half of all people in Asia who live in the zone of the category IX and higher are from developing countries (Table 10). In the zone of the category IX and higher live 73% of the population from developing countries who inhabit this zone. In percentages, Nepal and Bhutan hold the record among all developing countries with 100% in the percentage share of the population living in the zone of the category VIII and IX and higher. They are followed by the Philippines with 94%, Iran with 70% and Kyrgyzstan and Turkey with 68%. Pakistan with 81% living in the zone VI and VII was hit by an earthquake of intensity of VIII in 2005 killing more than 73,000 people (Frankenberg, Laurito, & Thomas, 2015) and causing an estimated \$5 billion in damage (World Bank Independent Evaluation Group, 2006). High number of deaths was associated with densely populated area. In contrast, one of the strongest earthquakes ever, with maximum intensity of XI, is one from 1964 which hit Alaska's sparsely populated area ending with only few deaths (Kusky, 2008). From the data, it appears that Sri Lanka and Cambodia are among the safest countries, which are completely in the zone of the category V or lower, followed by 86% of the population in Thailand and Vietnam with 84%. Malaysia and North Korea are spread only in the zones V and VI. Turkmenistan with a great majority of population settled in the zone VI (71%) has suffered an earthquake in 1948, which claimed 110,000 lives (USGS, 2014).

Table 10. Vulnerability of the population in the countries in Asia for 2015 in relation to the zone of the maximum possible intensity of earthquakes

Country	Asia										Total popul.
	Modified Mercalli earthquake intensity										
	≤ V		VI		VII		VIII		≥ IX		
Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%		
India	189,650	15	552,822	45	366,338	30	91,677	7	29,997	2	1,230,484
China	202,650	15	599,194	43	319,000	23	239,352	17	26,090	2	1,386,286
Philippines			2,566	3	3,173	3	68,412	71	21,731	23	95,882
Nepal							17,617	55	14,521	45	32,138
Turkey			6,443	8	18,700	24	44,515	56	9,346	12	79,004
Indonesia	12,374	5	17,489	7	144,004	58	70,777	28	5,426	2	250,070
Iran			659	1	24,820	28	56,417	65	5,206	6	87,102
Bangladesh			84,453	46	61,461	34	32,970	18	4,274	2	183,158
Myanmar	1,280	2	3,185	6	26,481	48	21,846	40	2,468	4	55,260
Kyrgyzstan			16	0	1,822	31	2,482	43	1,516	26	5,836
Bhutan							1,932	63	1,138	37	3,070
Uzbekistan	334	1	10,176	33	15,992	52	3,475	11	554	2	30,531
Pakistan			77,209	38	87,713	43	39,070	19	276	0	204,268
Tajikistan			39	1	3,810	54	2,989	42	259	4	7,097
Russia	24,713	69	9,555	27	1,363	4	219	1	119	0	35,969
Afghanistan	2,952	8	3,800	11	8,525	24	20,241	57	59	0	35,577
Armenia					59	2	3,214	98			3,273
Iraq	3,475	10	19,034	57	9,027	27	2,013	6			33,549
Syria	1,856	8	8,865	38	10,512	45	1,972	8			23,205
Kazakhstan	9,246	58	3,467	22	1,312	8	1,808	11			15,833
Azerbaijan					7,063	81	1,607	19			8,670
Jordan	88	1	51	1	5,211	82	1,043	16			6,393
Georgia			1,791	37	2,459	51	526	11			4,776
Turkmenistan	829	14	4,196	71	611	10	246	4			5,882
Mongolia	323	10	2,050	66	607	20	105	3			3,085
Lebanon					4,160	100	1	0			4,161
Yemen	3,051	9	18,127	55	11,941	36					33,119
Laos	4,063	55	1,724	23	1,548	21					7,335
Maldives	11	3			441	97					452
Thailand	62,546	86	9,589	13	355	0					72,490
Vietnam	79,019	84	14,764	16	63	0					93,846
North Korea	2,755	11	21,641	89							24,396
Malaysia	23,635	85	4,276	15							27,911
Sri Lanka	21,451	100									21,451
Cambodia	18,555	100									18,555
Total	664,856	16	1,477,181	36	1,138,571	28%	726,526	18%	122,980	3%	4,130,114

<sup>(1)</sup> Population in thousands

In Africa the least number of people, among other continents, live in the zone of the category IX and higher, only 0.1% in percentages (Table 11). Only Algeria is in this most vulnerable zone. In the tectonically calmest zone of category V or

lower live 50% of the population of this continent. Africa is the most populous country and, according to the estimation, the fourth place with a population in the world by 2050 — Nigeria is in the zone of the category V and lower. The same case is with Burkina Faso, Mali, Chad, Benin, Sierra Leone, Liberia, Central African Republic, Gambia, Mauritius, Comoros, Mayotte, and Seychelles Islands. The most vulnerable countries are Algeria and Morocco in the north, and countries around The Great Rift Valley as Ethiopia, Eritrea, Uganda and Burundi.

Table 11. Vulnerability of the population in the countries in Africa for 2015 in relation to the zone of the maximum possible intensity of earthquakes

Country	Africa										Total popul.
	Modified Mercalli earthquake intensity										
	≤ V		VI		VII		VIII		≥ IX		
Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%		
Algeria	5,640	15	5,882	15	9,646	25	15,718	41	1,137	3	38,023
Ethiopia	7,178	8	35,701	40	30,531	34	16,354	18			89,764
Uganda			24,362	63	9,278	24	4,808	13			38,448
Morocco	7,218	19	8,184	22	18,417	49	3,861	10			37,680
Eritrea			651	11	1,631	29	3,438	60			5,720
D.R. of the Congo	50,385	60	15,656	19	15,556	19	2,448	3			84,045
Tunis			5,453	52	3,398	32	1,606	15			10,457
Burundi			1,263	14	6,546	73	1,119	13			8,928
Mozambique	4,764	20	13,951	59	3,886	17	883	4			23,484
Djibouti							703	100			703
South Africa	7,890	18	31,375	70	4,866	11	482	1			44,613
Zimbabwe	3,810	23	10,184	62	1,980	12	394	2			16,368
Somalia	14,662	95	229	1	305	2	208	1			15,404
Botswana	1,424	84	173	10	19	1	78	5			1,694
Kenya	4,644	12	26,082	65	9,134	23	65	0			39,925
Egypt	350	0	26,832	32	57,243	68					84,425
Rwanda			2,835	27	7,669	73					10,504
Malawi			8,861	57	6,710	43					15,571
Libya			809	12	5,664	88					6,473
Ghana	16,667	63	4,993	19	4,718	18					26,378
Zambia			11,478	78	3,319	22					14,797
Sudan	37,120	87	4,460	11	852	2					42,432
Guinea	10,904	96	152	1	244	2					11,300
Lesotho			1,932	90	210	10					2,142
Swaziland			820	80	202	20					1,022
Namibia	2,256	98	13	1	43	2					2,312
Cameroon	11,881	59	8 345	41							20,226
Senegal	6,843	51	6 673	49							13,516
Madagascar	21,159	88	2 913	12							24,072
Togo	4,467	68	2 110	32							6,577
Angola	19,028	92	1 767	8							20,795
Cape Verde			567	100							567

Niger	18,482	98	403	2							18,885
São Tomé and P.			178	100							178
Guinea-Bissau	1,566	91	161	9							1,727
Rep. of Congo	4,610	97	121	3							4,731
Mauritania	3,986	97	120	3							4,106
Gabon	1,688	96	69	4							1,757
Nigeria	164,911	100									164,911
Burkina Faso	18,509	100									18,509
Mali	17,657	100									17,657
Chad	12,376	100									12,376
Benin	9,448	100									9,448
Sierra Leone	7,115	100									7,115
Liberia	5,550	100									5,550
Central Afr. Rep.	4,877	100									4,877
Gambia	1,781	100									1,781
Mauritius	1,301	100									1,301
Comoros	1,067	100									1,067
Tunis	801	100									801
Libya	585	100									585
Mayotte	322	100									322
Seychelles	97	100									97
Total	515,019	50	265,758	26	202,067	20%	52,165	5%	1,137	0%	1,036,146

<sup>(1)</sup> Population in thousands

North America is the third place with a population in the zone of the category IX and above, after Asia and South America (Table 12). The most vulnerable countries are Guatemala, El Salvador and Costa Rica. Guatemala has 93% of the population in the zones of the categories VIII and IX and more, Costa Rica 85%, El Salvador about 80% and Mexico 25%. Haiti with 64% of the population in category VIII and the rest in category VII was struck by the earthquake in 2010 which destroyed 24.4% of households and damaged another 41.5% (Kolbe et al., 2010), killing over 220,000 (Frankenberg et al., 2015). 65.9% of all deaths were children under the age of 12 (Kolbe et al., 2010).

Table 12. Vulnerability of the population in the countries in North America for 2015 in relation to the zone of the maximum possible intensity of earthquakes

North America											
Country	Modified Mercalli earthquake intensity										Total popul.
	< V		VI		VII		VIII		≥ IX		
	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	
Guatemala			116	1	980	6	7,523	46	7,709	47	16,328
Mexico	17,163	14	11,033	9	60,880	51	24,569	21	5,530	5	119,175
Nicaragua	595	8	1,776	25	1,479	21	1,360	19	1,968	27	7,178
Salvador			131	2	1,500	19	5,118	64	1,230	15	7,979
Costa Rica					755	14	4,075	78	403	8	5,233
Panama			2,343	68	529	15	369	11	211	6	3,452
Haiti					3,702	36	6,512	64			10,214
Dominican Republic					7,740	62	4,833	38			12,573
Jamaica							2,957	100			2,957
Cuba			6,159	53	3,905	34	1,581	14			11,645
Trinidad and Tobago					141	10	1,251	90			1,392
Saint Lucia							169	100			169
Honduras	925	11	4,583	53	3,067	35	127	1			8,702
St. Vinc. and the Gren.							123	100			123
Grenada							97	100			97
Antigua and Barbuda							68	100			68
Saint Kitts and Nevis							35	100			35
Belize			151	53	105	37	30	10			286
Total	18,683	9	26,292	13	84,783	41	60,797	29	17,051	8	207,606

<sup>(1)</sup> Population in thousands

In South America, 56% of the population of the continent live in the zone of the category V and lower (Table 13). Paraguay, Uruguay and Suriname are completely in this zone, as well as 95% of Brazil. The most endangered is the population of Ecuador (over 99% live in the zones of the categories VIII and IX and more), Chile (98%), Peru (around 73%) and Colombia (46%). Argentina and Venezuela are also in danger.

Table 13. Vulnerability of the population in the countries in South America for 2015 in relation to the zone of the maximum possible intensity of earthquakes

South America											
Country	Modified Mercalli earthquake intensity										Total popul.
	≤ V		VI		VII		VIII		≥ IX		
	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	
Peru			265	1	8,121	25	9,764	31	13,701	43	31,851
Chile					307	2	11,882	66	5,722	32	17,911
Ecuador					65	0	13,750	86	2,121	13	15,936
Argentina	30,036	69	4,684	11	4,733	11	2,210	5	1,834	4	43,497
Colombia	171	0	9,645	18	18,384	35	23,840	45	602	1	52,642
Venezuela	108	0	7,418	24	11,140	36	11,651	38	560	2	30,877
Bolivia	930	8	3,733	33	6,317	56	215	2			11,195
Brazil	191,349	95	9,892	5	151	0					201,392
Guyana	672	90	76	10							748
Paraguay	7,773	100									7,773
Uruguay	3,670	100									3,670
Suriname	437	100									437
Total	235,146	56	35,713	9	49,218	12	73,312	18	24,540	6	417,929

<sup>(1)</sup> Population in thousands

Among the countries of Oceania, only American Samoa is whole in the zone of the category V or lower (Table 14). Fiji, Solomon Islands, Kiribati and Tuvalu are in their entirety in the zone of the category VIII. Palau and Vanuatu are countries that completely belong to the zones of the categories VIII and IX and higher, and in Papua New Guinea 58% of the population live in these areas.

Table 14. Vulnerability of the population in the countries in Oceania for 2015 in relation to the zone of the maximum possible intensity of earthquakes

Oceania											
Country	Modified Mercalli earthquake intensity										Total popul.
	≤ V		VI		VII		VIII		≥ IX		
	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	Popul. <sup>(1)</sup>	%	
Papua New Guinea			194	3	2,582	39	2,433	37	1,433	22	6,642
Vanuatu							155	55	127	45	282
Palau							26	99	0	1	26
Fiji							925	100			925
Solomon Islands							719	100			719
Kiribati	8	8					92	92			99
Tonga	19	18					86	82			105
Marshall Islands	1	2					61	98			62
American Samoa	104	100									104
Total	132	1	194	2	2,582	22	4,496	61	1,560	13	8,964

<sup>(1)</sup> Population in thousands

## Conclusions

Earthquakes are serious sources of danger to people around the world, but not everyone is equally at risk. Earthquakes are particularly dangerous because they cannot be predicted, and therefore public cannot be informed and prepared for a possible disaster, nor it is possible to organize the evacuation. As the epicentre of the earthquake is closer to the populated area, injuries, casualties and damages will be more numerous. The earthquake itself does not kill people, but people are dying because of the demolition of the buildings, roads and other structures. What makes earthquakes deathly is not their strength, but the way in which buildings are constructed. The more we know of the most seismically active areas on Earth, possible power of earthquakes and the consequences that may follow, it will be more possible to assess the possible damage and make the necessary plans to minimize human and material losses.

Population growth puts more people at risk. With the increase of the population, more people will live and work in areas that are vulnerable to geological and other natural hazards. In developed countries, the accidents are mainly rated by material, economic or environmental losses, while in developing countries disasters are often measured with the number of lives lost. The population of the world is continuously increasing, and in percentages the largest increase is in the zone of the category VIII and that is up to 56%, where earthquakes can be so strong that they can knock down even some modern buildings. In relation to the World population by zones, 78% of the population who inhabit zone of the intensity  $\leq V$  live in developing countries, in zone of the intensity VI 84% of the population resides in developing countries, in zone of the intensity VII 91%, in zone of the intensity VIII 89%, and in zone of the intensity  $\geq IX$  62% of the population from that zone are coming from developing countries. Because of the complexity which arises from numerous causes, there is no one who could claim that the earthquakes are the only reason why the zone with most destructive earthquakes is the least populated one. The largest population growth is in Asia and Africa, and that is in developing countries. The greatest population growth is in the cities of underdeveloped countries, due to natural increase and migrations of population. The poorest and the most marginalized ones are becoming even more vulnerable living in poorly-built buildings within megacities. Earthquakes in such circumstances could end with possible serious consequences.

Recent earthquake in Italy, occurred on August 24, 2016 showed that even in developed country implementation of anti-seismic law which required renovation of old buildings and making them earthquake resistant is being



disregarded. This suggests that in future studies even some developed countries should be included in similar research.

An earthquake cannot be stopped or controlled, but people can reduce the destruction that earthquakes can cause. Large cities that are located in earthquake zones are impossible to move to another location, but it is possible to construct buildings resistant to earthquakes. This can be done with strict control and respect of the rules of construction. More efficient construction should rely on understanding how earthquakes affect the structure of the building. Even the seismic performance of existing structures could be improved and that could be done in many ways, adding external or internal reinforcements mainly of steel in the shape of the letter X or placing layers of rubber and steel under the foundations of buildings to absorb and reduce the effects of earthquakes.

People can avoid or reduce the risk of earthquakes and other natural phenomena that can turn into a disaster with appropriate preventions, mitigation of consequences of accidents, willingness to help and with quick reactions. One of the problems is that the priority is rarely given to training, equipment and organization of mechanisms for coordination in emergency situations, and we are often unprepared when disasters come. Possibility of secondary disasters as tsunamis and fires should be also determined. Understanding why the geological phenomena are occurring in the way they are, when and where are they most likely to happen, and what could be their impact on humans are the main issues that need to be taken into account in any planning.

#### References

- Bolt, B. (2005). *Earthquakes: 2006 Centennial Update — The 1906 Big One* (5<sup>th</sup> Ed.). W. H. Freeman and Company, 10–14, 293–297
- Brewer, C. A. (2013). *ColorBrewer 2.0* [Online] Available from: <http://colorbrewer2.org/>
- Center for International Earth Science Information Network (CIESIN), Columbia University; and Centro Internacional de Agricultura Tropical (CIAT). (2005). *Gridded Population of the World (GPW)* [Data file], Version 3. Palisades, NY: CIESIN, Columbia University. Available from <http://sedac.ciesin.columbia.edu/gpw>.
- Frankenberg, E., Laurito, M., & Thomas, D. (2015). Demographic impact of disasters. In J. D. Wight (Ed.) *International Encyclopedia of the Social and Behavioral Sciences* (2<sup>nd</sup> Ed.). Elsevier. doi: <http://dx.doi.org/10.1016/B978-0-08-097086-8.31059-5>
- Gates, A. E., Ritchie, D. (2007). *Encyclopedia of Earthquakes and Volcanoes* (3<sup>rd</sup> Ed.). New York. Retrieved from <http://1.droppdf.com/files/loH4O/encyclopedia-of-earthquakes-and-volcanoes.pdf>

- Harding, L. (2001, February 17). Indian quake widens rifts between the castes. *The Guardian*. Available from <https://www.theguardian.com/environment/2001/feb/17/naturaldisasters.climatechange>
- Haynes, B. E., Freeman, C., Rubin, J. L., Koehler, G. A., Enriquez, S. M., & Smiley, D. R. (1992). Medical response to catastrophic events: California's planning and the Loma Prieta earthquake. *Annals of Emergency Medicine*, 21(4), 368–374. doi: [http://dx.doi.org/10.1016/S0196-0644\(05\)82652-6](http://dx.doi.org/10.1016/S0196-0644(05)82652-6)
- Kolbe, A. R., Hutson, R. A., Shannon, H., Trzcinski, A., Miles, B., Levitz, N., Puccio, M., James, L., Noel, J. R., & Muggah, R. (2010). Mortality, crime and access to basic needs before and after the Haiti earthquake: a random survey of Port-au-Prince households. *Medicine, Conflict and Survival*, 26(4), 281–297. doi: <https://dx.doi.org/10.1080/13623699.2010.535279>
- Kusky, T. (2008). *Earthquakes: Plate Tectonics and Earthquake Hazards*. New York: Facts On File, Inc., New York.
- Munich Re. (2011). *NATHAN world map of natural hazards*. Retrieved from [http://www.munichre.com/site/corporate/get/documents/mr/assetpool.shared/Documents/0\\_Corporate%20Website/\\_Publications/302-05972\\_en.pdf](http://www.munichre.com/site/corporate/get/documents/mr/assetpool.shared/Documents/0_Corporate%20Website/_Publications/302-05972_en.pdf)
- Naghii, M. R. (2005). Public health impact and medical consequences of earthquakes. *Revista Panamericana de Salud Pública*, 18(3), 216–221. doi: <http://dx.doi.org/10.1590/S1020-49892005000800013>
- Oxfam. (2005). *The tsunami's impact on women*. Available from <http://oxfamilibrary.openrepository.com/oxfam/bitstream/10546/115038/1/bn-tsunami-impact-on-women-250305-en.pdf>
- Özerdem, A. (2006). The mountain tsunami: afterthoughts on the Kashmir earthquake. *Third World Quarterly*, 27(3), 397–419. doi: <http://dx.doi.org/10.1080/01436590600587846>
- Özerdem, A., Barakat, S. (2000). After the Marmara earthquake: lessons for avoiding short cuts to disasters. *Third World Quarterly*, 21(93), 425–439. doi: <http://dx.doi.org/10.1080/713701047>
- UNEP. (2001). *United Nations Environment Programme Earthquake Intensity Zones* [Data file]. Retrieved from <http://geodata.grid.unep.ch/options.php?selectedID=58&selectedDatasettype=16>
- United Nations. (2012). *Statistical Annex: Country Classification statistics* Available from [http://www.un.org/en/development/desa/policy/wesp/wesp\\_current/2012country\\_class.pdf](http://www.un.org/en/development/desa/policy/wesp/wesp_current/2012country_class.pdf)
- USGS. (2014.) *Earthquakes with 1,000 or More Deaths 1900–2014*. Retrieved from [http://earthquake.usgs.gov/earthquakes/world/world\\_deaths.php](http://earthquake.usgs.gov/earthquakes/world/world_deaths.php)
- World Bank Independent Evaluation Group (2006). *Hazards of Nature, Risks to Development — An IEG Evaluation of World Bank Assistance for Natural Disasters*. The International Bank for Reconstruction and Development, The World Bank, Washington. Retrieved from <http://documents.worldbank.org/curated/en/396321468161661084/pdf/366150Hazards0and0risks01PUBLIC1.pdf>