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Analyzing Earthquake, Tsunami, and Liquefaction Disaster Mitigation Preparedness in Central Sulawesi, Indonesia

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Abstract

The purpose of this study was to analyze the preparedness for the mitigation and evacuation of earthquakes, tsunamis and liquefaction that occurred in Central Sulawesi. This research uses qualitative methods with a disaster risk analysis approach. The results showed that there is a need for a special health crisis response unit for efforts to overcome health crises. The lack of optimal capacity of health workers in overcoming health crises results in low handling of disasters that occur. It is necessary to carry out proper mitigation training in handling mitigation, prevention and preparedness for the types of liquefaction disasters. Training needs to be held with the aim of increasing the quality of health service capacity in disaster emergencies by utilizing local non-governmental organizations to carry out rapid assessments in disaster emergencies, and appropriate government policies are required in the event of a disaster emergency.

Keywords

Disaster Mitigation, Liquefaction, Earthquake, Tsunami, Health

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Introduction

Central Sulawesi is one of the provinces that often experiences geological events because it is traversed by two quite active faults, namely PKF (Palu Koro Fault) and MF (Matano Fault), both of which are found around the Palu Valley (Widyaningrum, 2012). In addition, several areas in Central Sulawesi Province are quite vulnerable because they have poor soil contours due to the presence of quaternary deposits consisting of fluviatile and alluvium deposits (Widyaningrum, 2012). The geological condition of Central Sulawesi Province can create dangerous potentials.

Some of these vulnerable areas are in Palu City and its surroundings. Based on the historical record of disasters in Central Sulawesi Province, especially Palu City and its surroundings, it has a fairly large potential for geological disasters. The National Earthquake Study Center recorded that there had been ten geological disasters in Palu City and its surroundings before 2018 with the majority having a magnitude of more than Mw 5.0 and some of which caused a tsunami (National Earthquake Study Center, 2018). Then, on September 28 2018, the Palu Donggala Earthquake which previously occurred had caused devastating damage and fatalities. This earthquake also has a complete phenomenon due to the movement of faults, tsunamis, landslides and liquefaction events that have a very large impact.

Based on the earthquake incident, it shows that earthquake events have a cycle and can cause many victims. In this case, there is a need for disaster risk reduction, especially earthquakes, tsunamis, and liquefaction, as well as well-targeted disaster management efforts. So it also requires risk analysis of earthquakes, tsunamis, and liquefaction. In this research, disaster risk analysis is made based on Law no. 24 of 2007 (Republic of Indonesia, 2007) and United Nation International Strategy for Disaster Reduction (United Nations International Strategy for Disaster Reduction, 2009). The purpose of this research is to study and analyze physical and social vulnerability to disasters in Palu City, Donggala Regency, Sigi Regency, and Parigi Moutong Regency. Then determine the recommendations for mitigating the earthquake, tsunami and liquefaction disaster.

Disaster Risk Analysis

The earthquake, tsunami, and liquefaction risk mapping in this study has certain criteria and parameters that may not be much different from other institutions and institutions but still has the same basic mapping study principal parameters. Earthquake, tsunami and liquefaction risk assessments are based on three agreed parameters in the Hyogo Framework for Action (United Nations, 2005), namely vulnerability, capacity and threat. The disaster risk analysis approach is used to show the relationship between vulnerabilities, capacities, and threats (hazards) that form the perspective of a region's disaster risk level.

Based on this approach, the level of disaster risk depends very much on the level of threat of a disaster in an area, the level of vulnerability of the area under threat, and the level of capacity of the area at risk. Disaster risk analysis is basically determining 3 risk parameters and is presented in both spatial and non-spatial terms. Disaster risk assessment is used as a basic tool in implementing disaster management in an area. This implementation is intended to reduce disaster risk. Then, efforts to reduce disaster risk can be carried out by minimizing the threat of the area, reducing the vulnerability of the area under threat, and increasing the capacity of the area under threat.

In this study we use the principles of disaster risk analysis in the data of the disaster in Palu City, Donggala Regency, Sigi Regency, and Parigi Moutong Regency in the earthquake, tsunami, and liquefaction disaster that occurred on September 28, 2018.

Methodology

Risk analysis is a basic research tool for disaster risk management to examine disaster risk factors and provides a basis for designing and practicing steps in reducing disaster risk and impact. Risk analysis is a process for understanding the nature of risk, for determining the level of risk, and for providing recommendations for decisions that need to be made, as well as for actions to be taken (IEC, 2019). In this article, the methods of earthquake, tsunami, and liquefaction risk analysis use parameters such as threat (hazard), vulnerability, and capacity.

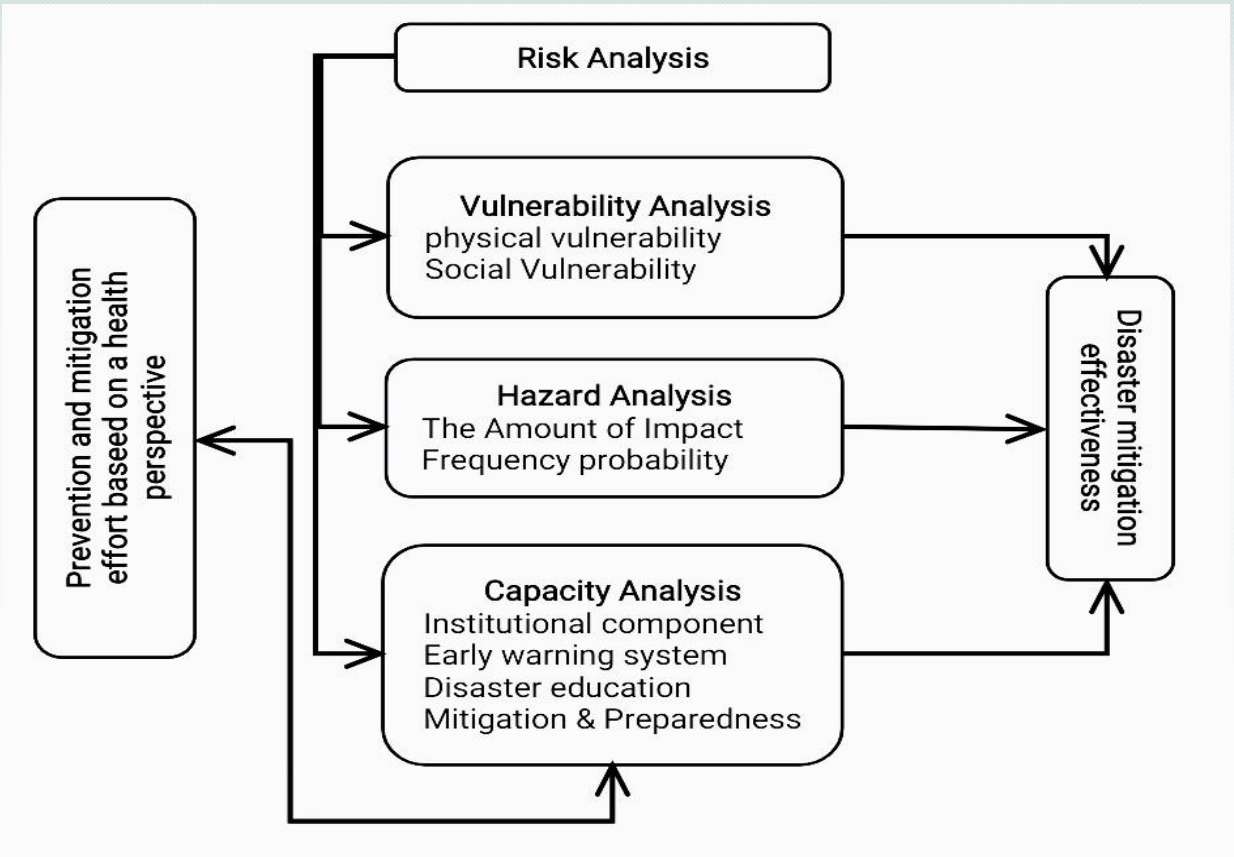

Figure 1: Analysis Method

Based on this conceptual chart, we examine several questions about the risk components of earthquakes, tsunamis and liquefaction to summarize the necessary information so that appropriate suggestions and recommendations provide appropriate disaster mitigation effectiveness analysis results as well: What is the preparedness of the community and government in disaster mitigation in Sulawesi Central especially in the city of Palu and its surroundings? Have the efforts taken have reached disaster mitigation effectiveness? What are the post-disaster conditions and obstacles in overcoming the risk of earthquakes, tsunamis and liquefaction in Palu City and its surroundings? What is the impact of the involvement of outsiders in assisting with earthquake, tsunami and liquefaction disaster relief in Palu City and its surroundings? How should disaster mitigation, preparedness and management be implemented after an earthquake, tsunami, and liquefaction to achieve effectiveness in disaster mitigation? Which suggestions and recommendations must be fulfilled to reduce the risk of earthquakes, tsunamis and liquefaction?

Analysis

Vulnerability is a combination of conditions that are influenced by physical, social, economic and environmental factors or processes that increase the vulnerability of an individual, community, asset or system to the impact of hazards (UNISDR, 2009). In this study, vulnerability is determined by two variables, namely social and physical analysis. Social vulnerability is the limit of a community to the consequences of natural disasters which have an impact on its ability or endurance in mitigating and recovering from and preparing for the impact of disasters (Niekert D., 2011). Physical vulnerability is a component that can be lost or damaged if exposed to a threat. The capacity analysis is intended to identify the strengths and resources available in reducing the level of risk, or impact of an earthquake, tsunami, and liquefaction. Community resources are evaluated by analyzing available strengths such as institutional components, early warning indices, disaster education, mitigation, and preparedness.

After the capacities, threats are characterized, the next step is to estimate the frequency analysis. Frequency analysis is used to estimate how likely it is that various incidents or hazards will occur. Frequency is a measure of the number of recurring events per unit of time. The inverse of the return period (frequency) is the probability that the event is exceeded, that is, the probability that the

event equals or exceeds within one year. Since earthquakes, tsunamis, and liquefaction rarely occur in certain regions, estimating their probability is a very difficult task with high yield uncertainty.

Decisions about risk management can be made using risk management keys as given in Table 1.

Table 1.
Risk Management Matrix

Level of risk Action	Action
Low Risk	Low risk is acceptable. Measures to reduce risk or reduce further harm should be implemented in conjunction with safety enhancements and other mitigations.
Medium Risk	Medium risk is acceptable in the short term. Plans to reduce risks and mitigate hazards should be included in future
High Risk	Unacceptable high risk. Measures to reduce risk and hazard mitigation should be implemented as soon as possible.
Very High Risk	Unacceptable high risk. Measures to reduce risk and hazard mitigation should be implemented as soon as possible.

Results

Central Sulawesi Province is a province on the island of Sulawesi, which is in the central part of the province with the capital city of Palu. The province, with an area of 61,841.65 square kilometers, is divided into 12 districts, 1 city, 175 sub-districts and 2,009 villages or wards. Geographically, Central Sulawesi Province is located between 2 ° 22′ – 3 ° 48 ′ South Latitude (LS) and 119 ° 22' – 124 ° 22 ′ East Longitude (BT) which borders Gorontalo Province to the north, South Sulawesi Province and Southeast Sulawesi to the south, and surrounded by the Makassar Strait to the west, and bordering Maluku Province on the east (Ministry of Health of the Republic of Indonesia, 2019).

13 Districts or Cities in Central Sulawesi Province are in a high risk class for the threat of floods, earthquakes, tsunamis, landslides, volcanoes, social conflicts, epidemics and disease outbreaks (Ministry of Health of the Republic of Indonesia, 2019).

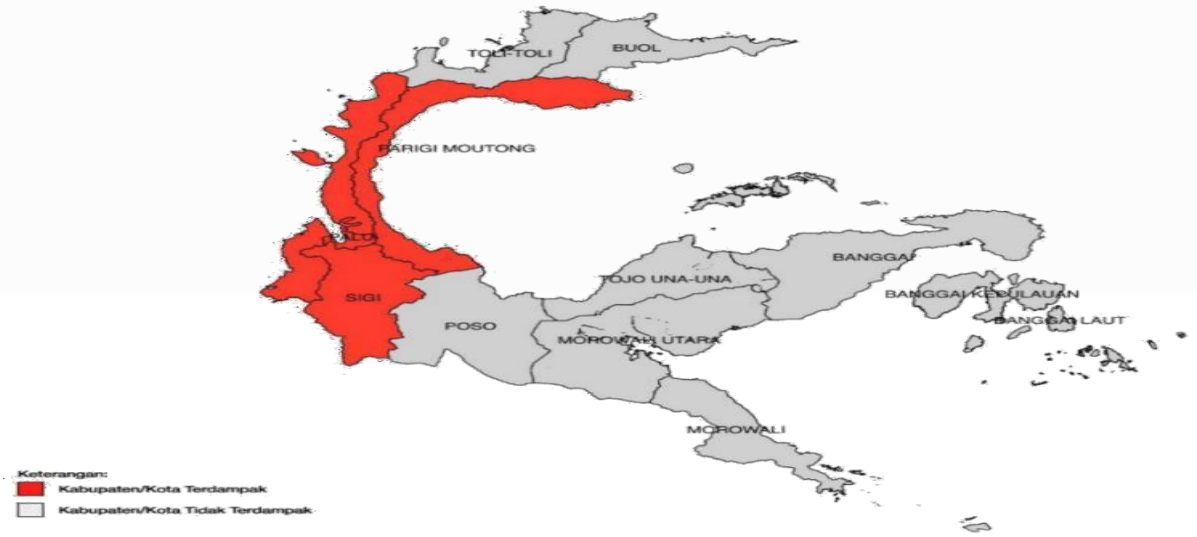

Figure 1: Map of Districts/ City Affected by Earthquake, Tsunami and Liquefaction

Demographics, Palu City shows a population with a population density of 911.69 (people / KM2), while the population density in Donggala, Sigi and Parigi Moutong Regencies is below the average (251-400 people / km2) (Southeast Sulawesi Provincial Health Office, 2017).

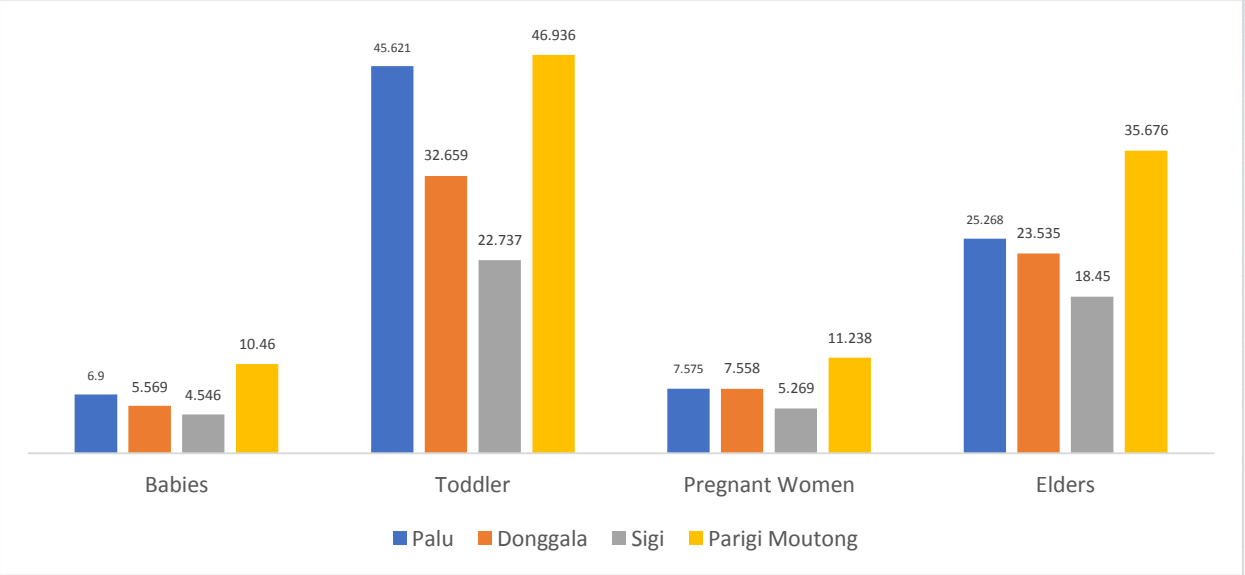

Figure 1: Number of Vulnerable Populations in 4 Districts / Cities affected by the earthquake in Central Sulawesi Province

Based on Table 2, it is illustrated that Palu City and Parigi Moutong Regency have vulnerable groups above 20%, while Donggala and Sigi Regency have vulnerable groups below 20%. This shows a high level of vulnerability in Palu City and Parigi Moutong Regency.
The health profile of the affected regency or city that has met the minimum standard of availability of health service facilities is Palu City with 39 health facilities consisting of 29 community health centers, 5 government hospitals and 5 private hospitals. For Puskesmas and hospitals, all districts / cities have met minimum standards except for Sigi Regency with 21 health facilities consisting of 19 public health centers and 2 government hospitals (Kementerian Kesehatan Republik Indonesia, 2019).

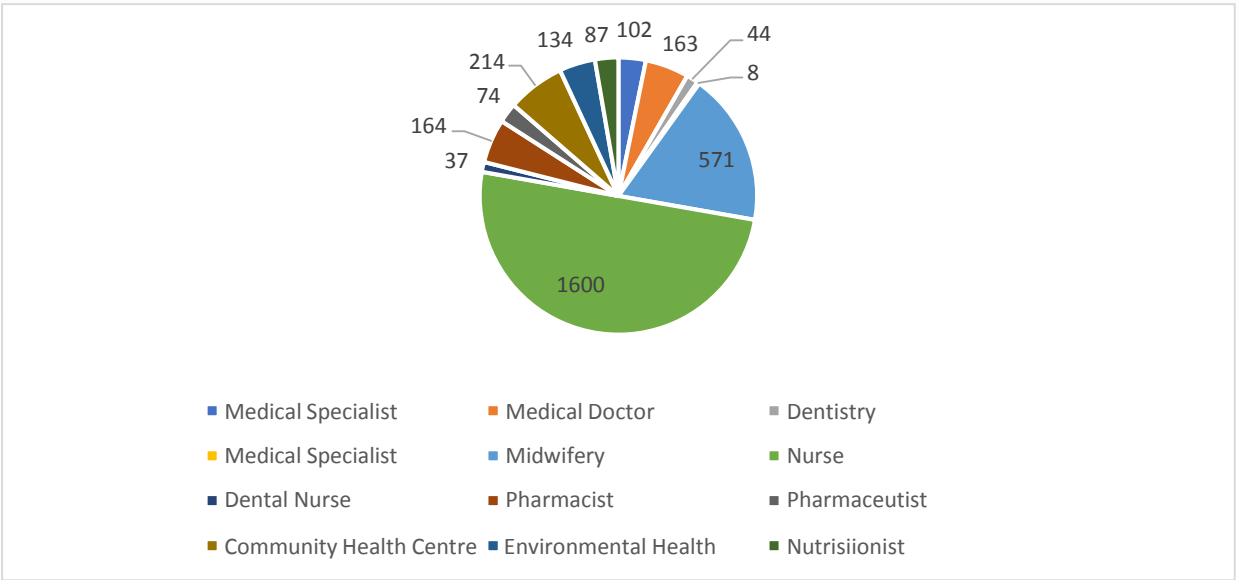

Figure 2: Number of Health Workers in 4 Districts or Cities affected by the earthquake in Central Sulawesi Province

Based on the availability of health facilities, the city of Palu has met the minimum standards of availability of specialist doctors and general practitioners. Donggala Regency has not met the minimum standard for the availability of midwives while Donggala and Sigi Regencies have not met the minimum standard for the availability of nurses.

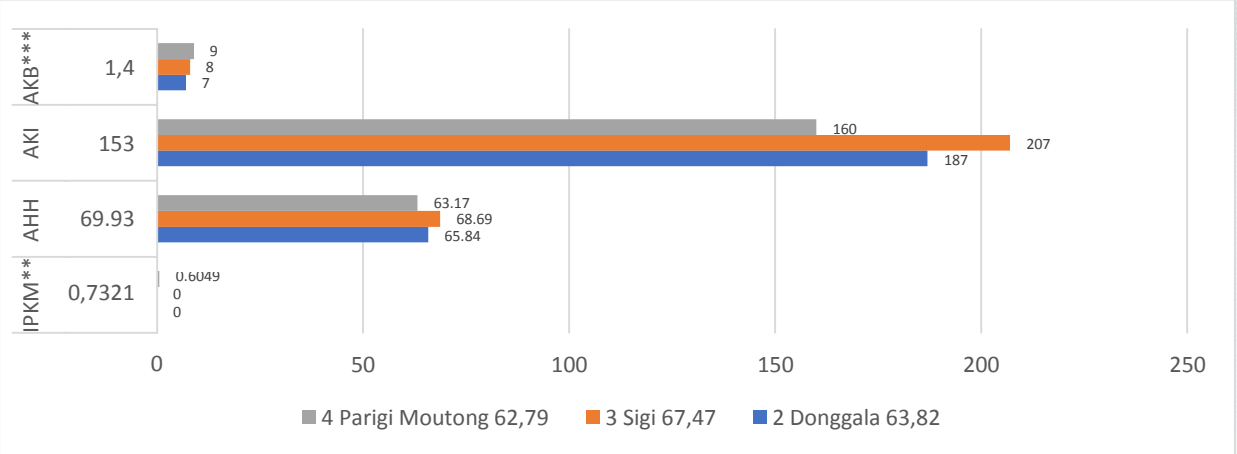

Figure 3: Health Profiles in 4 Districts / Cities Affected by Earthquake, Tsunami and Liquefaction in Central Sulawesi Province

Based on Indonesian Health Profile Data for 2018, the national Maternal Mortality Rate (MMR) in 2015 was 305 per 100,000 live births, while the MDGs target was 102 per 100,000 live births. Then, all districts / cities have MMR lower than the national figure but still above the MDGs target. The results of the Indonesian Demographic and Health Survey (IDHS) in 2017 show the Infant Mortality Rate (IMR) of 24 per 1,000 live births. Based on the table, it can be seen that all affected districts / cities have IMR less than the national figure. Palu City and Donggala Regency are high-risk areas while Sigi and Parigi Moutong Districts are at moderate risk (National Disaster Management Agency, 2019). Based on health profile data, the population density in the affected districts / cities is below the average, except that Palu City has a relatively dense population, besides that the proportion of vulnerable groups in Palu City and Parigi Moutong Regency is high.

The only number of health service facilities that meet the minimum standards for health service facilities is Palu City, while for the availability of hospitals and community health centers all have met the minimum standards except for Sigi Regency. Likewise, for the availability of doctors and specialist doctors, only Palu City meets the minimum standards. As for the midwives, only Donggala district did not meet the minimum standard of availability for a midwife, while nurses from Donggala and Sigi District had not met the minimum standard for availability of nurses. AHH is still below the national AHH, the infant mortality rate and maternal mortality rate are already below the national target, but for maternal mortality, it is still above the MDGs target. Affected districts or cities have good enough HDI and IPKM with moderate to high HDI ranges, while for IPKM, all affected districts or cities have IPKM scores above the Provincial IPKM.

According to the Ministry of Health of the Republic of Indonesia, the Health Crisis Center shows that most of the population in the affected districts / cities have a high vulnerability to earthquakes, even for Palu City 100% of the population has high vulnerability, likewise with Sigi Regency, almost all of its residents have high vulnerability to earthquake disasters earth. As for the tsunami, Donggala Regency was the most affected area, where most of the population had a high level of vulnerability (89.6%) to tsunamis. On the other hand, in Sigi District, the population is not vulnerable to tsunamis (0%). Meanwhile, for the other two affected districts / cities, the population with high vulnerability to tsunamis is less than 40%.

Analysis of moderate to high levels of physical vulnerability to earthquakes and tsunamis, most buildings in Palu City, Donggala, Sigi and Parigi Moutong Districts have high physical vulnerability to earthquakes, even for Palu City 100% of the buildings have high vulnerability. Most of the buildings in Palu City and Donggala Regency have high vulnerability to tsunamis (96.9%). For Parigi Moutong District, the moderate to high physical vulnerability levels are almost the same, while Sigi Regency does not have physical vulnerability to tsunamis.

Based on the results of the 2018 Health Crisis Management review data, the achievement for policy indicators or regulations related to the health crisis / disaster in the 4 affected districts or cities is still below 50%, besides that they also do not have a disaster management plan document. In the early warning indicators of Sigi Regency, the achievement has been 100%. In addition, Parigi Moutong district does not exist at all. Palu City achieved the highest capacity strengthening indicator (70%), while the lowest was Donggala Regency (20%). Mitigation and preparedness efforts have been implemented in all affected districts / cities, but the achievement for Donggala and Parigi Moutong Districts is still below 30%. Regarding community empowerment, all districts or cities have formed active alert villages and disaster resilient villages proclaimed by BNPB.

Discussions

The chronology of the earthquake disaster in Central Sulawesi Province occurred on September 28 2018 at 14.00 WIB, with a magnitude of Mw 5.9 with the epicenter 8 km northwest of Donggala at a depth of 10 km. The next earthquake with a magnitude of Mw 7.7 occurred on Friday, September 28 2018 at 17.02 WIB at a depth of 10 km, again shaking Palu City and Donggala Regency, Central Sulawesi Province. This was followed by an earthquake of 7.4 on the Richter scale, followed by tsunami waves in several areas of Donggala coast and Talise beach, Palu, which came 20-25 minutes after the earthquake. BMKG has ended tsunami early warning since 28 September 2018 at 17.36 WIB. Earthquake shocks were felt in Donggala Regency, Palu City, Parigi Moutong Regency, Sigi Regency, Poso Regency, Tolitoli Regency, Mamuju Regency and even Samarinda City, Balikpapan City, and Makassar City. The earthquake triggered a tsunami up to a height of 5 meters in Palu City. According to the Head of the Center for Data, Information and Public Relations of BNPB, Sutopo Purwo Nugroho, the earthquake that occurred "was a type of shallow earthquake due to the Palu Koro fault activity, which was generated by deformation by the movement mechanism of the horizontal slice-slip structure." BMKG issued a warning of a tsunami following the earthquake that occurred in the coastal areas of Donggala Regency, Palu City and parts of the northern coast of Mamuju Regency. The tsunami is predicted to have a height of 0.5–3 meters with arrival time in Palu City at 18.22 WITA. At 18:27 WITA, a tsunami wave with a height of 6-7 meters crashed along the west coast of Central Sulawesi covering the areas of Donggala Regency and Palu City.

Earthquake shocks also result in liquefaction. Liquefaction is a phenomenon when granular deposits lose strength and toughness and then change from solid to liquid, due to an increase in pore water pressure due to the effect of cyclic shock (Jefferies & Been, 2015). The phenomenon of liquefaction is the result of an earthquake in an area composed of loose sand layers with a shallow upper boundary of the saturated water content zone (<9.0 m), and is caused by the intensity and duration of earthquake shocks and the distance from the epicenter (Study Center National Earthquake, 2018). This phenomenon of liquefaction can result in several events including a rapid decline (quick settlement), unbalanced building foundations (tiling) or (differential settlement), and drying of well water which turns into non-cohesive material (Widyaningrum, 2012).

The two locations that have experienced liquefaction are Petobo and Perumnas Balaroa in Palu City. The location of the Balaroa Perumnas is at a distance of 2.6 km from the Palu-Koro fault line, while the location of Petobo Village is 1 km from the Palu-Koro fault line. During liquefaction, there is an increase and decrease in land surface. Some parts collapsed 5 meters, and some parts rose up to 2 meters. Hundreds of houses in Petobo Village were buried by black mud with a height of 3-5 meters. Happening after the earthquake, the ground in the area quickly turned into mud which immediately dragged the buildings above it. The houses of residents in the Perumnas Balaroa Complex, West Palu District collapsed, as if they were sucked into the ground. This liquefaction incident also occurred in Jono Oge Village and Sidera Village in Sigi Regency.

Determination of the Status of Earthquake and Tsunami Emergency Management in Central Sulawesi Province, through Governor Decree Number: 466/459 / BPBD, concerning Determination of Emergency Status for Earthquake and Tsunami Disaster Management in Central Sulawesi Province, September 29 2018, for 14 days since 29 September to 11 October 2018. This status was later extended through the Governor's Decree Number: 466/463 / BPBD concerning the Extension of the Emergency Response Status for Earthquake and Tsunami Management in Central Sulawesi Province, for 14 days until 26 October 2018. Analysis of the Center for Volcanology and Geological Disaster Mitigation (PVMBG) estimates that the earthquake shocks on the island of Sulawesi were due to the movement of the Palu Koro Fault. This fault is embedded and extends from North to South, dividing the Palu area. The Palu Koro fault originally started from the sea, but mostly stretched across the land, which really seemed to split Palu City into two parts. There are also other faults under the soil of the island of Sulawesi, such as the Matano Fault which according to experts also has the potential for a major earthquake disaster like Palu Koro

Health Sub Cluster Efforts

In an effort to overcome health problems due to the earthquake, tsunami and liquefaction

disaster, it is carried out in accordance with existing health problems. The mitigation effort that has been carried out is by dividing several teams into certain sectors. Based on the 2018 Health Crisis Management Review, the prevention sectors are divided into 9 sectors, namely: Health Information Team, Health Logistics Team, Health Promotion Team, Health Service Sub Cluster, Disease Control and Environmental Health Sub Cluster, Nutrition Management Sub Cluster, Sub Reproductive Health Cluster, Mental Health Sub-Cluster and Victim Disaster Sub-Cluster (DVI)
In handling, the 9 sectors consist of Provincial Offices, Regency or City Offices, Ministry of Health of the Republic of Indonesia, BNPB related NGOs, namely WHO Indonesian Representatives, WHO staff, non-governmental organizations, such as PMI, NGOs, Community Organizations, and Professional Organizations accordingly. With the problem areas and expertise they have (Ministry of Health of the Republic of Indonesia, 2019).
According to the 2018 Health Crisis Management Review, in implementing this earthquake, tsunami, and liquefaction disaster management, there are obstacles experienced, as follows:
Resources, it was found that all services could not be used as before in the emergency response phase until the third day; Health facilities in the form of medical devices and almost all health workers are not actively providing services; Inadequate logistics of drugs and consumables; Health workers who are victims of disasters and who fled from their homes do not quickly return to their assignments; Health workers who do not receive incentives like some other health workers who are mobilized from outside the region do not work optimally.
Access: found locations in mountainous areas and road infrastructure that were damaged by the earthquake such as Kulawi, Dolo and South Dolo Districts in Sigi Regency and several sub-districts in Donggala Regency so that access to several areas affected by the disaster was difficult.
Health Crisis Management: it was found that coordination was not working optimally between the Provincial and District or City Health Offices, hospitals, volunteers or non-governmental organizations (NGOs) and the community due to a lack of understanding of disaster management and what stages were carried out when it occurred disaster; policies that are not oriented towards disaster risk reduction; The existing risk assessment and analysis are not used by either the local government or the community, including health agencies, with many settlements and health service facilities in the red zone; Rapid assessments do not inform the real condition; and too much command and bureaucracy

Conclusion

The results found the importance of mitigation and prevention and preparedness for a new type of disaster, namely liquefaction. However, many non-governmental organizations are willing to help efforts to overcome the health crisis so that in the future they can become partners for the government in efforts to overcome the health crisis. It was found that the absence of a special health crisis response unit at the Health Office resulted in less than optimal efforts to overcome the health crisis. It was found that the capacity of health workers at the Provincial and District / City Health Offices and Puskesmas in responding to health crises was still insufficient.
Based on the results it is suggested that it is necessary to advocate for stakeholders to review policies so that they are oriented towards disaster risk reduction, the UPTD Health Crisis at the Central Sulawesi Provincial Health Office should be revived. Study and analysis of existing risks to form the basis of local government and community policies, including health agencies; Provincial and District / City Health Offices need to follow up and evaluate efforts to overcome health crises that have been made to improve policies; There needs to be a strengthening of community capacity in the first line when an emergency occurs, such as First Aid and Basic Living Assistance (BHD) using community empowerment. PRRBK involves local NGOs; It is necessary to increase the capacity of the Provincial and District / City Health Offices to carry out RHA and utilize local NGOs / EMTs to conduct rapid assessments of health needs in a disaster situation; and Provincial and District / City Health Offices need to strengthen coordination with members of the health sub-cluster from local capacities and cross-sectoral cooperation in health crisis management.

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