Model of regional vulnerability against CO₂Toxic Gas disasters at Mount Dieng (case study: Timbang Crater, Batur Sub-District, Banjarnegara District)

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Abstract. One of the sub-districts that are vulnerable to toxic gas disasters is Batur Sub-district, Banjarnegara District. For that people living in the vicinity of the crater should always be ready for the national disaster of toxic gas that had killed 149 people on February 20, 1979 did not happen again. The purpose of this research is to make the model of vulnerability of area to toxic gas disasters of CO₂ Timbang crater in Batur Sub-District by using Analytical Hierarchy Process (AHP). The population in this study is the entire head of the family located in Batur Sub-District, Banjarnegara District, Central Java Province, amounting to 37 heads of household. To take the sample used Simple Random Sampling method. Data analysis techniques through weighting of the three aspects are exposure, sensitivity, and adaptive capacity. In each aspect the parameters are weighted using input from the experts by the AHP method. The vulnerability of the area to the toxic gas catastrophic CO₂ is classified into three levels of vulnerability are, low, medium, and high. Based on the research result, the vulnerability level in Batur sub-district is only divided into two classes, namely for the vulnerability class being found in 6 villages are, Pekasiran Village, Pesurenan, Sumberejo, Karang Tengah, Bakal, and Dieng Kulon. For the high grade, there are 2 villages: Batur, and Kepakisan. This happens because the level of exposure and sensitivity is much higher than the adaptive capacity of the community.

1. Introduction
Dieng plateau area is the result of the formation of volcanic processes that still exist until today. This is evidenced by the activity in some craters in the area of Volcano Dieng. The craters are still active and remove the mud and smoke that billow free in the air. The gas emissions produced by some craters have been known for a long time [1]. Gas or minerals generated from the activity of these craters can threaten the lives of the people around the crater. Volcanic gases are usually water vapor, carbon dioxide, sulfur dioxide, hydrogen sulfide, and hydrogen chloride [2]. The dangerous volcanic gas from this dieng mountain area is carbon dioxide (CO₂). Acute exposure to volcanic-produced carbon dioxide has resulted in severe morbidity and mortality in Japan, Italy, Africa and Indonesia [3, 4]. Considering the occurrence of sudden and fatal gas offensive events in places such as Mammoth Mountain (USA), Hakoda (Japan), Mefite D'Ansanto (Italy), Lake Nyos and Monoun (Cameroon),

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and Dieng Volcanic complex (Indonesia) [5,6,7,8,9]. The potential for volcanic gas disasters was demonstrated in Lake Nyos, Cameroon, in 1986, when more than 1,700 people died in the release of about a quarter of a million tonnes of carbon dioxide stored in crater lakes [10]. CO₂ flow or gas explosion similar to that caused the 1986 Nyos Lake disaster in Cameroon from the Sinila and Sigludug craters. The latest lethal gas burst in 1979 occurred in 149 people caught in gas clouds [11]. For that people who live in the vicinity of the crater should always be ready to alert the national disaster disaster poisonous gas that had killed 149 people on February 20, 1979 did not happen again. Vulnerability can be defined as a combination of factors that determine the extent to which a person’s life, livelihood or general well-being is threatened by extreme natural events [12]. Research on the vulnerability of the region to the toxic gas disaster was analyzed using Analytical Hierarchy Process (AHP) method because the variables used in this study have not been of any importance. Vulnerability is a complex problem that needs to be grouped into problems that are then organized into hierarchical forms to make the problem seem more systematic. AHP is derived from the opinions of disaster experts as a key input in weighting its vulnerability. After the calculation is completed the value is entered by grouping for three categories namely low, medium, and high according [13]. From this AHP method can be obtained classification of vulnerability class of the region against toxic gas disasters of low, medium, and high CO₂.

2. Material And Methods

2.1 Study Area
The location of this research is in Batur District, Banjarnegara Regency, Central Java Province. The astronomy of Batur Sub-district is at 7°11’0" LS – 7°14’30" and 109°47’0" BT – 109°54’0" BT. Geographically, Batur Sub-district is adjacent to Batang regency in the north, directly adjacent to Wonosobo regency in the south, Pejawaran subdistrict in the south and Wanayasa subdistrict in the east. Batur District consists of 8 villages: Batur, Sumberejo, Pekasiran, Pesurenan, Kepakisan, Karang Tengah, Bakal, and Dieng Kulon Village. The case study is in Timbang Crater is located in Sumberejo Village.

2.2 Data collection
Variable from research which used as analysis of vulnerability of CO₂ toxic gas disaster in Timbang Crater are: Exposure Level, with indicator of population density, and land use. Sensitivity level with indicators of vulnerable age population and area of productive land. Adaptive Capacity Level with indicators of education level, health facilities, and disaster mitigation socialization. Vulnerability is a function of exposure, sensitivity, and adaptive capacity expressed through V = (E.S: CA) or can be formulated mathematically as follows:

\[ V = \frac{ES}{CA} \]  

Where V is Vulnerability, E is Exposure, S is Sensitivity and CA is Capacity Adaptive. The primary data was obtained from field survey conducted in the research area by conducting interviews to the community regarding the required data. Primary data collection on mitigation socialization was conducted by field survey, with purposive sampling method was taken 37 respondents which is the existing village community in Batur. The results of these interviews are then converted to tabular data. Secondary data is sourced from the institution related to the collection of research data.

2.3 Data Analysis
The analysis used is descriptive analysis to explain the potential of this disaster is seen from physical condition such as geology, altitude, slope, and rainfall and map of CO₂ gas distribution from PVMBG. The analysis used is spatial analysis to explain the vulnerability of toxic gas disasters is seen from the potential map of toxic gas disasters covered with maps of settlements in the district of Batur.
Vulnerability analysis of CO$_2$ toxic gas is obtained through weighting of three aspects of exposure, sensitivity, and adaptive capacity. In each aspect it has a parameter that is weighted using input from experts via the AHP method. The vulnerability of the area to the toxic gas catastrophic CO$_2$ is classified into three levels of vulnerability ie, low, medium, and high.

3. Results and Discussion

3.1 Potential Hazard CO$_2$ Toxic Gas Disaster of Mount Dieng in Batur District

Potential hazard areas of disaster are areas that are physically influenced by the characteristics that make up the area of potential disaster. In Batur District, the physical condition is in the form of geological conditions, rainfall, and topography that affect the potential for toxic gas disasters of CO$_2$. In addition, Geological Agency PVMBG in 2011 also issued a map of CO$_2$ gas concentration in the Dieng mountain area. The potential of this toxic gas disaster is usually out of the craters that exist in the Dieng mountains. The characteristics of the Dieng Crater is different when the increase in volcanic activity. In addition to the potential of toxic gases that can come out of several existing craters, the potential for this poisonous gas disaster can also come out of every soil in Batur District. This can be seen from the potential map of toxic gas disasters above, it is seen that the area of Batur sub-district is mostly potential of CO$_2$ gas starting from low concentration around 0.03-0.49% to high around 25.00-100.00%. The potential can occur if there is an increase in volcanic activity followed by a local earthquake that disrupts the stability of surrounding soil (figure 01).

3.2 Vulnerability of CO$_2$ Toxic Gas Disaster in Batur District

Toxic gas disaster-prone area is an area that has characteristics of poisonous gas potential disaster. Being a disaster prone area because the area that has the potential of disaster is utilized by the surrounding population into settlements or agricultural land. Sumberejo village is one of the most vulnerable areas because this Sumberejo village is a toxic gas flow area that comes out of the Timbang Crater when volcanic activity increases. Plus the number of residents who inhabit this Sumberejo village, even the activity of the population was mostly done around the lips of this Timbang Crater to grow crops (figure 02).

3.3 Weight Parameter Vulnerability of Territory to CO$_2$ Gas Disaster

The weight of this vulnerability parameter is taken from some experts' opinions, such as Surip, Head of Observation Post Diapi Volcano, Dr. Raditya Jati SSi, Msi, Director of Disaster Risk Reduction BNPB, Dr. Muzani Msi, Lecturer of Disaster Studies, Graduate School, Faculty of Social Sciences, Jakarta State University, and Dr. Suroto, former Head of Volcanology Center for Volcano Disaster Mitigation (PVMBG), and Former Head of Geological Agency of the Ministry of ESDM.

3.4 Population Density

For population density study area there are only 2 classes, 25% is population density with medium class, which includes 2 villages are Sumberejo and Bakal. In this study area is dominated by high population density with percentage up to 75% of the total number of villages present in CO$_2$ toxic gas hazard areas. These villages are, Batur, Pekasiran, Kepakisan, Karang Tengah, Pesurenan, and Dieng Kulon Village. High population density will surely increase its exposure, since population density is the parameter that most influences the exposure aspect of vulnerability of the region to CO$_2$ toxic gas.

3.5 Land Use

For the use of their own land known that land use is very high in the prone area that is about 62% spread in 5 villages of Batur, Sumberejo, Pekasiran, Pesurenan, and Karang tengah. While 25% in medium category with 2 villages of Bakal and Dieng Kulon, while in the low category of 13% in the village of Pesurenan. Land use in Batur District is mostly used as agricultural land and these settlements are causing high levels of exposure in Batur District.
3.6 Regional Vulnerability Exposure to Toxic Gas Disasters
Based on Table 5 the identification of the level of exposure in each village is then done scoring assess the level of exposure in each village. Based on the scoring results it can be seen that there is the highest classification of exposure found in the class (> 2.90) with 50% with 4 villages in it, while in the middle class (2.16-1.90) with 38% with 3 villages in it, and in the category of low (<2.16) by 12% with one village in it (figure 03).

3.7 Age Population Vulnerable
The vulnerable aged population in this batur area is 75% in the high category covering 6 villages are Batur, Sumberejo, Kepakisan, Bakal, Karang Tengah, and Dieng kulon Village. While 25% are in the medium category which includes 2 villages are Pesurenan and Pekasiran. The more vulnerable the population will be the higher the level of sensitivity in affecting vulnerability.

3.8 Area of Productive Land
The area of productive land in this batur district is 75% in the medium category covering 6 villages are Batur Village, Sumberejo, Pekasiran, Kepakisan, Bakal, and Karang Tengah Village. While 25% are in the low category which includes 2 villages are Pesurenan and Dieng Kulon. Due to the increasingly productive land area, the higher is the sensitivity level.

3.9 Sensitivity of Regional Vulnerability to Toxic Gas Disasters
Based on Table 5, the sensitivity level was identified in each village and then scoring the level of sensitivity in each village. Based on the scores can be seen that the classification of sensitivity there are only three classes, the highest is in the high category (2.66) with 63% and there are 5 villages. While in medium category (1.98-2.66) only 25% with 2 villages, and for low grade (<1.98) with 12% with 1 village (figure 04).

3.10 Basic Education Level
Based on the data processing of villages with a very high number of basic education is the village of Batur, Sumberejo and Bakal with a percentage of about 38%. For its own number Sumberejo Village has a very large number of 2,516 inhabitants. For the classification at a moderate level there is one village is Kepakisan village with the number of primary education level of 701 people with a percentage of 12%. While in the low classification there are 4 villages with low level of education that is Pesurenan, Pekasiran, Karang Tengah and Dieng Kulon with the largest percentage that is 50%. The higher the level of basic education in a region, the more vulnerable the area will be, it is because most of the population has the highest education only until junior high school (SMP). While the lower the basic education level of an area, the smaller the vulnerability in the area, this is because each population is higher than junior high school level, so can graduate high school or college (PT).

3.11 Health facility
For the health facility vulnerability rate is still very high with a percentage of 63%. That is because there are five villages that do not have health facilities of the five villages are Batur Village, Pesurenan, Kepakisan, Bakal, and Karang Tengah. While there are only three clinics in three villages, which means its level of vulnerability of the medium category with a percentage of 37%. The three villages are Sumberejo Village, Pekasiran and Dieng Kulon. This health facility is inversely proportional to the level of vulnerability, because the more complete the health facility in a region then the level of vulnerability is lower.

3.12 Mitigation Socialization
Based on the results of field surveys by conducting interviews of residents in the study area known responses of residents to CO2 toxic gas disasters before the disaster, when the disaster, and after the disaster. From the responses of residents to the toxic gas disasters CO2 can be seen that the actions
taken in each research area tend to have differences. In three villages that have a distance not too far from the Timbang crater as Sumberejo, Pekasiran, and Batur are usually before the disaster they always pay attention to the natural signs that occur around the crater. Not infrequently residents around the crater to know the release of CO$_2$ toxic gas by burning tires used around the crater. When the fire that burned the old tire was dead then the local people immediately concluded that the Timbang Crater is issuing CO$_2$ toxic gas, and vice versa. When there is a toxic gas disaster, the residents who live in these three villages will flee to a safe place, and wait for the foresters from the interested parties to return to their respective homes when conditions are already conducive. Although there are still people around the crater that remains active around the crater. As for the 5 other villages due to the distance of the village with the crater away then the community remains active as usual despite the increased activity of Timbang crater. To socialize the mitigation only Sumberejo Village ever conducted socialization or training about the danger of this poisonous gas. However, other villages have not been held in socialization or training, only socialization and training of more disasters to landslides.

3.13 Adaptive Capacity of Regional Vulnerability to Toxic Gas Disasters
Based on Table 5, the adaptive capacity level of each village was identified, then scoring the adaptive capacity level in each village. Based on the scores it can be seen that the highest adaptive capacity classification is in the medium category (1.03-1.69) and high (> 1.69) with the percentage of each 38%, with each of them 3 villages. For the high category of the three villages are Sumberejo Village, Pekasiran, and Dieng Kulon. For the medium category there are also three villages of Pesurenan, Kepakisan, and Karang Tengah. While the rest are in low grade (<1.03) with 24% and 2 villages in it ie Batur and Bakal Village. The higher the adaptive capacity level of an area will minimize its vulnerability to this CO$_2$ toxic gas disaster (figure 05).

3.14 Regional Vulnerability Model on Toxic Gas Disasters CO$_2$
The results of vulnerability scores resulted in classifications that were divided into three classes, namely low vulnerability classes (<1.94), medium (1.94-6.23), and high (> 6.23) in each village. Based on the scoring it can be seen that this research area is dominated by medium vulnerability class with a percentage of 75%. Then 25% of them are high vulnerability classes. Areas that have a high degree of vulnerability of the region to high toxic gas disasters are found in two villages: Batur, and Kepakisan. That is because both villages have high levels of exposure and sensitivity but for low adaptive capacity. There are 6 villages belonging to this medium vulnerability class such as Pekasiran, Pesurenan, Karang Tengah, Bakal, Dieng Kulon and Sumberejo villages. Despite high levels of exposure and sensitivity, the area has a high adaptive capacity that can be said to adapt to this CO$_2$ toxic gas disaster. Although Sumberejo Village is in a moderate classification in its level of vulnerability, Sumberejo Village is a very vulnerable village to this CO$_2$ toxic. In addition to social factors such as the number of settlements and dense population, the number of people who use the lands around the crater, the physical condition also greatly affects the level of vulnerability of the disaster in Sumberejo village. Physical conditions that include geology, topography, rainfall, wind direction and speed as well as small rivers around the Timbang Crater (figure 06).

4. Conclusion
Potential catastrophic high CO$_2$ gas toll, Sumberejo Village, Pekasiran, and part of Batur Village. This is because the location of the craters located in the three villages. Potential poison gas disasters can also threaten 5 other villages, this is due to the large concentrations of CO$_2$ gas in the soil deposits in Batur District, which whenever can come out in case of instability in the soil. For the level of vulnerability itself in the District of Batur including very vulnerable, it is due to the many settlements of residents who inhabit the potential area of this poison gas disaster. In addition to settlements, the use of land around the crater used as agricultural land also makes this area more vulnerable. Just like the Sumberejo village is the village closest to the Timbang crater which is only 1 km, and many
citizens move around the Timbang crater lips for farming. As for the level of vulnerability itself, the Batur district is in the level of vulnerability of medium to high class. For the vulnerability class there are 6 villages are Pekasiran Village, Pesurenan, Sumberejo, Karang Tengah, Bakal, and Dieng Kulon, for high class high in 2 villages are Batur Village, and Kepakisan. This happens because the level of exposure and sensitivity is much higher than the adaptive capacity of the community. For a very vulnerable area it is Sumberejo Village, it is because the distance of Timbang crater with the village only 1 km, the number of residents who live and work the land around the crater. Apart from these social conditions, the wicked condition of Sumberejo village itself also greatly affects the vulnerability level of this CO₂ toxic gas disaster. Starting from the geological conditions, topography, rainfall, wind direction and speed, as well as small rivers that exist around this Sumberejo village. Each of these physical conditions contributes to the vulnerability of CO₂ toxic gas disasters in Sumberejo Village.

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