

Early Warning Experiences in Padang, Sumatra: The Bengkulu Earthquake of 12 September 2007

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1. BACKGROUND

On September 12 and 13, 2007, a series of large earthquakes originating from the Sunda Trench off the West coast of Sumatra struck Padang, the capital of West Sumatra Province. The first earthquake, at 18:10:23 (WIB, Western Indonesian Time), was recorded at a magnitude of M 7.9 at BMKG Jakarta, the National Agency for Meteorology, Climatology and Geophysics.

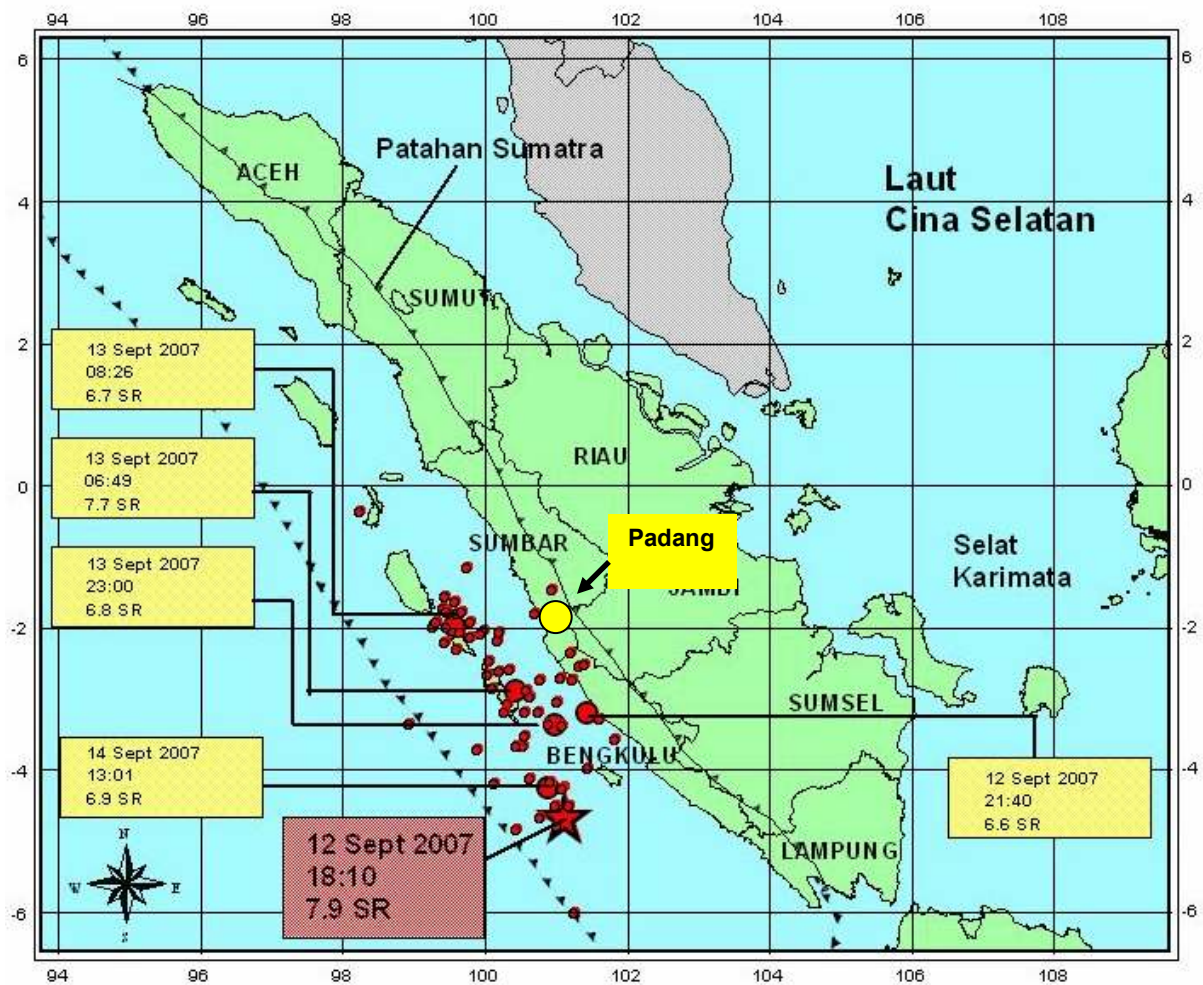


Figure. 1: Map of West Sumatra, as released by BMKG, with epicentre location of the magnitude 7.9 earthquake and main aftershocks.

The earthquake hypocenter was located offshore at 4.44 degrees South, 101.37 degrees East, at a depth of 34km. The slant distance to Bengkulu was about 130km, to Padang about 390km. This main event is the objective of this paper. However, this earthquake was followed by a series of medium to large aftershocks as shown in figure 1. It appears that seismic activity is migrating from SE to NE towards Padang, a distance of about 400km.

The map of West Sumatra shows the location of the main earthquake of 12 September 2007, origin time 18:10 WIB (11:10 GMT) off the coast of Bengkulu. Large aftershocks are also plotted. All times referred are in West Indonesian time (GMT +7 hours) and magnitudes correspond to Richter Magnitude. Arrowheads indicate the beginning of subduction of the Indo-Australian Plate beneath the Eurasian Plate while the toothed line marks the Sumatra fault, a tectonic surface expression associated with the subduction process.

The sequence of aftershocks from 12 to 16 September 2007 following large earthquakes is displayed in figure 2. Earthquakes located in the very same area have been accumulated in intervals of 5 hours. As can be seen, the number of aftershocks is gradually declining.

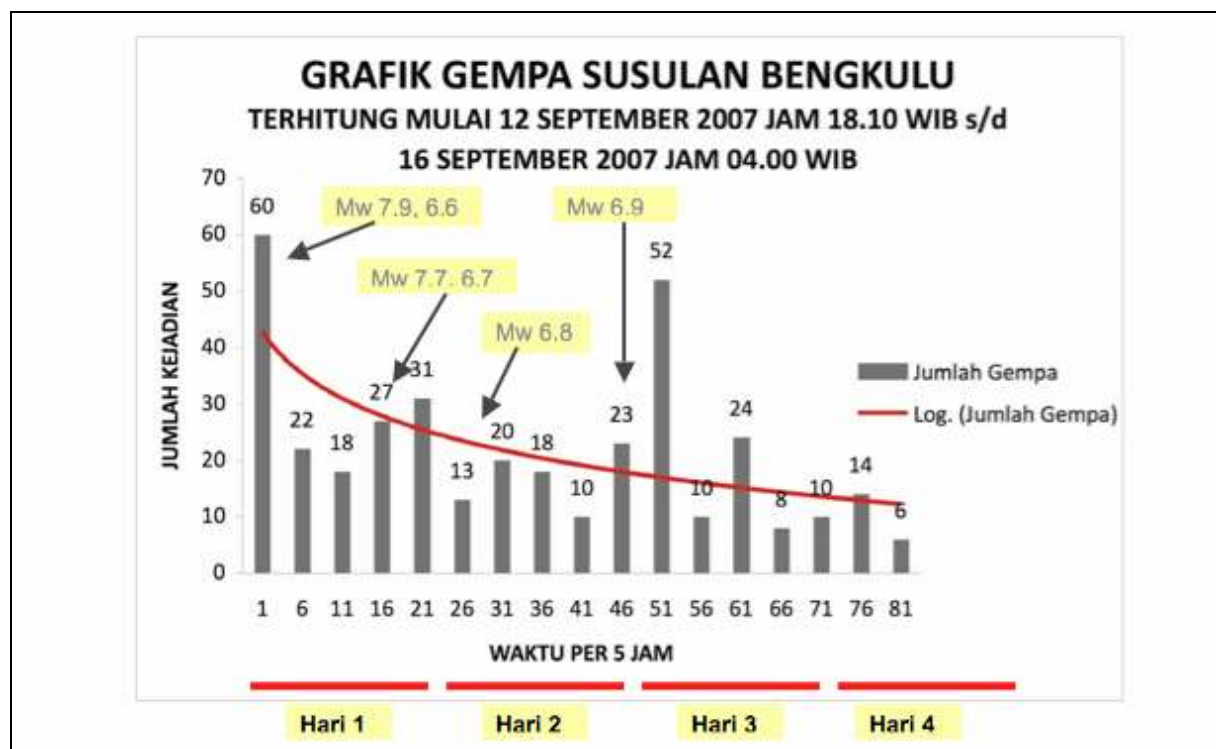


Figure 2. Seismic activity following the main earthquake and large aftershocks (source BMKG).

The time line shown in figure 3 puts subsequent observations and actions taken at the BMKG Warning Centre into perspective. Shown here are BMKG’s activities after the main event at 18:10:23 WIB (West Indonesian Time) finishing with the ‘All Clear’ after a little more than two hours. In two minutes seismic stations are indicating that the seismic P wave arrival has been detected and that data is being processed. This triggers the alarm in the Operations Room at BMKG to get the full attention of the operators: ‘heads up’! At this time contact is made with Bengkulu BMKG station to get a quick situation report. Bengkulu was significantly closer to the hypocenter than Padang. Felt intensities (on the Modified Mercalli Intensity Scale, MMI) are reported. After 4:07 minutes the earthquake location tool SeisComp 3, developed by GFZ Potsdam, delivers hypocenter location and magnitude. The seismic analysis tool developed by CEA (China Earthquake Networks Centre) follows seconds later. BMKG issues SMS messages containing the tsunami warning *potensi tsunami* being sent after

4:41 minutes and received by decision makers in Padang, so shortly after the ground shaking. At the same time information from people who have felt the event at Padang, Lampung, Jambi (all locations are in Sumatra) and Jakarta (!) is received. 4:37 minutes after the initial shock TV and radio stations are provided with information which the pass on to the general public. Aftershocks are recorded and widely felt. After 2 hours and 9 minutes the ‘all clear’ message is issued and the Tsunami Warning cancelled.

As stated by several sources,¹ the mayor of Padang announced guidance for evacuation to Padang citizens around 15 minutes after the earthquake via FM radio in response to the tsunami warning.

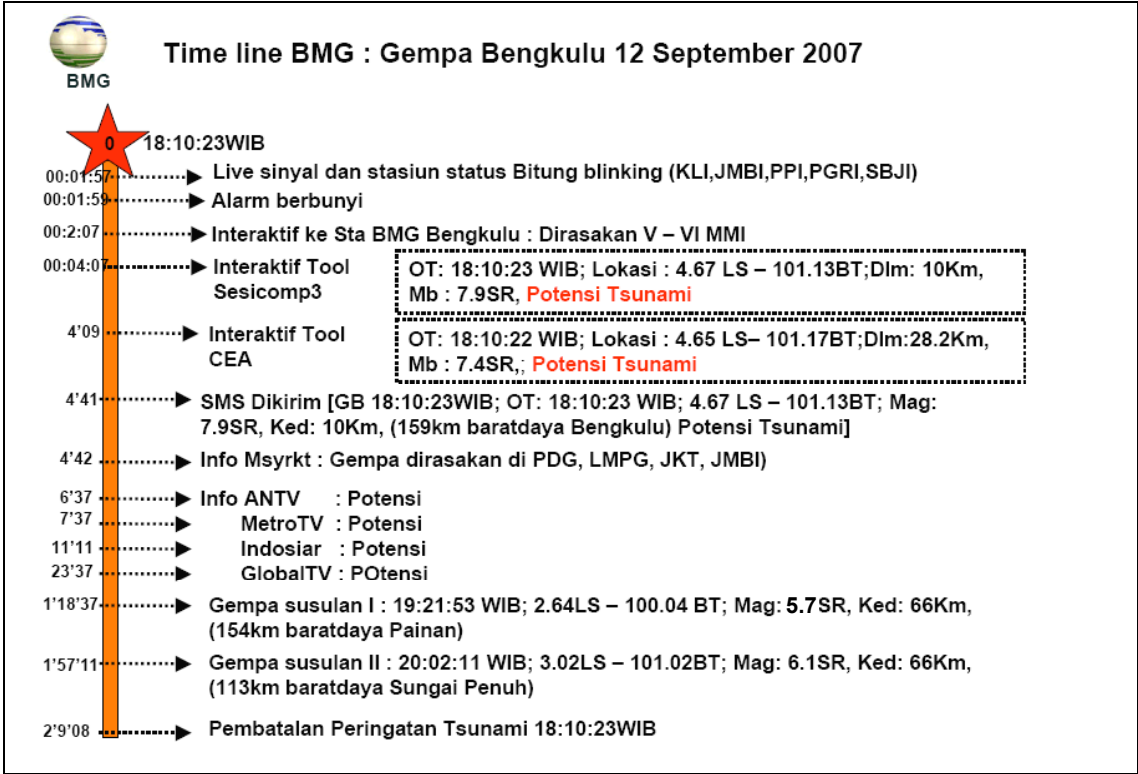


Figure 3: BMKG time line of the 12 September 2009 magnitude 7.9 earthquake.

As can be seen in figure 4, about 46 minutes after the magnitude 7.9 earthquake the tide gauge monitoring station located at Padang is recording a small tsunami with an amplitude of about 19cm peak-to-peak.

Around one and a half months later, from 29 October to 2 November 2007, GTZ IS-GITEWS conducted an explorative survey in Padang in order to shed some light on the experiences with the first earthquake and the subsequent tsunami warning information *potensi tsunami*. The survey used a standardized questionnaire to conduct interviews with 200 randomly selected citizens of Padang City who live in the “red zone” (elevation zone: 0-5 m in accordance to the ‘First Generation Elevation Zone and Evacuation Map of Padang City’, (figure 5) and/or were within that area at the time of the first earthquake.

¹ Key informant interviews conducted with representatives of different government and non-government institutions in Padang. The information obtained from above sources varied largely. In conclusion, it seems that the mayor actually did call for evacuation. The precise wording of the evacuation message, however, could not be clarified.

STASIUN PENGAMAT TIDE GAUGE PADANG

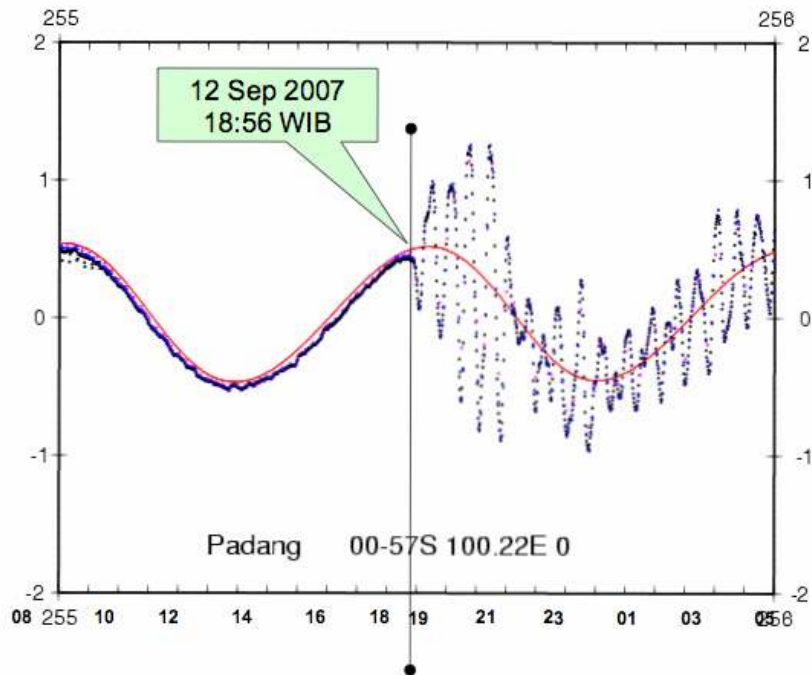


Figure 4: The tide gauge in Padang is recording a small tsunami at 18:56 WIB. The ordinate is scaled to 10cm intervals. Source BMKG.

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The survey does not claim to provide representative results for all Padang City but is considered explorative. It aims to approach the question of tsunami preparedness by providing answers to the following key aspects:

Respondents' actions after the earthquake had ended

- What percentage of respondents evacuated?
- How long after the first earthquake did those who evacuated actually start to do so?
- What did those respondents do who did not evacuate?

Information about potential tsunami

- What percentage of respondents received the information about a potential tsunami? What were their source and channel of information? How long after the earthquake did they receive the information and how did they perceive its content?

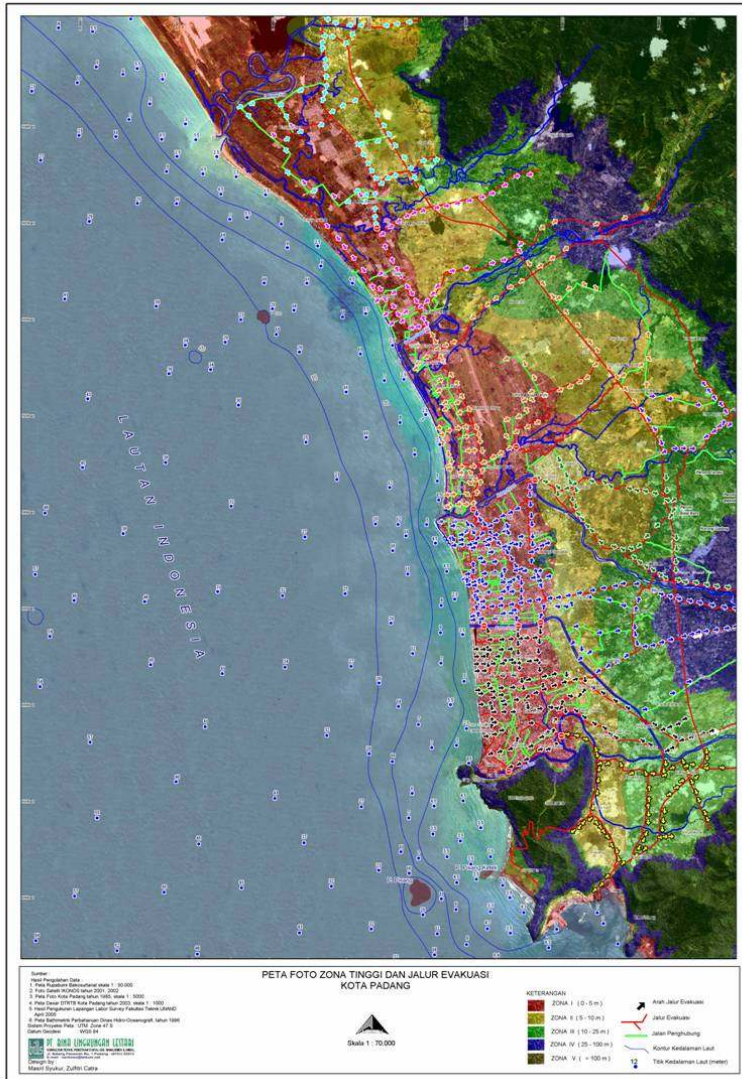


Figure 5: First generation of elevation zone and evacuation map of Padang as provided by the Padang Working Group.

2. MAIN FINDINGS

The two crucial issues for tsunami early warning are timely dissemination of comprehensible information about a potential threat (i.e. warning and guidance) and appropriate reaction by communities at risk. The survey recorded both: it documented a sequence of actions after the earthquake for each respondent and recorded source and channel of information on tsunami potential as well as timing of reception and perceived content.

Section A summarizes the respondents' actions performed after the earthquake had ended in two groups of those who performed some kind of evacuation action and those who did not, irrespective of what triggered these actions (i.e. ground shaking or tsunami warning). Section B examines the information respondents received regarding a potential tsunami threat and relates it to the respondents' actions.

A. RESPONDENT ACTIONS AFTER THE EARTHQUAKE HAD ENDED

How many respondents evacuated?

As figure 6 shows the majority of respondents did NOT evacuate at any time after the first earthquake. To an open question about what the interviewees did after the first earthquake had ended only 29 respondents answered that they evacuated while 9 respondents said they went away from the beach and 4 respondents stated to have gone to higher ground. The question recorded sequence of multiple (max. 5) actions for each respondent after the earthquake as well as the respective timing in minutes after the earthquake occurrence. In total 22 % of all respondents reacted with some kind of evacuation action to the potential tsunami threat. The majority of 78 % (158 respondents) neither started evacuation nor went away from the beach or to higher ground.



Figure 6: What was the reaction of those receiving the Tsunami warning message?

How long after the first earthquake did those who evacuated actually start to do so?

The major tsunami threat to Indonesian coastlines is that of a local tsunami. Arrival times of the first wave can be as short as 20 minutes after the earthquake—as experienced in Aceh (2004) . Therefore the time that remains to start evacuation is extremely limited—only a few minutes. A closer look at the group of those who stated to have evacuated (15 %, 29 respondents) provides an idea on the time after the earthquake that it took them to start moving to a safer place (see figure 7).



Figure 7: Timeline showing the minutes after EQ respondents (n=29) needed to start evacuating.

20 minutes after the first ground shaking at 18:10 WIB, 14 of the 29 respondents who evacuated had left for an evacuation area. After 30 minutes 4 more respondents had begun evacuation, accumulating to 62 % of all 29 respondents.

Some of the respondents who evacuated had initially already gone away from the beach or were on alert/ ready for evacuation; some contacted friends and relatives while others turned on TV and checked their belongings. Overall these cases provide an interesting insight into respondent behaviour after the first earthquake. Figure 8 presents six examples:

Case	Min	Action 1	Min	Action 2	Min	Action 3	Min	Action 4	Min	Action 5
I	5	On alert	15	On alert and ready to evacuate	30	Went away from beach/ coast	45	Evacuated		
II	5	Went away from beach	15	On alert and ready to evacuate	20	Evacuated				
III	10	Contact friends/ relatives	30	Check/ secure belongings	35	Went away from beach	40	Evacuated		
IV	10	Went away from beach	15	Evacuated						
V	10	Went away from beach	20	Evacuated						
VI	20	Turned on TV	35	Check/ secure belongings	45	Went away from beach	60	On alert	80	Evacuated

Figure 8: Selected cases illustrating action time lines (in minutes) after the earthquake had ended

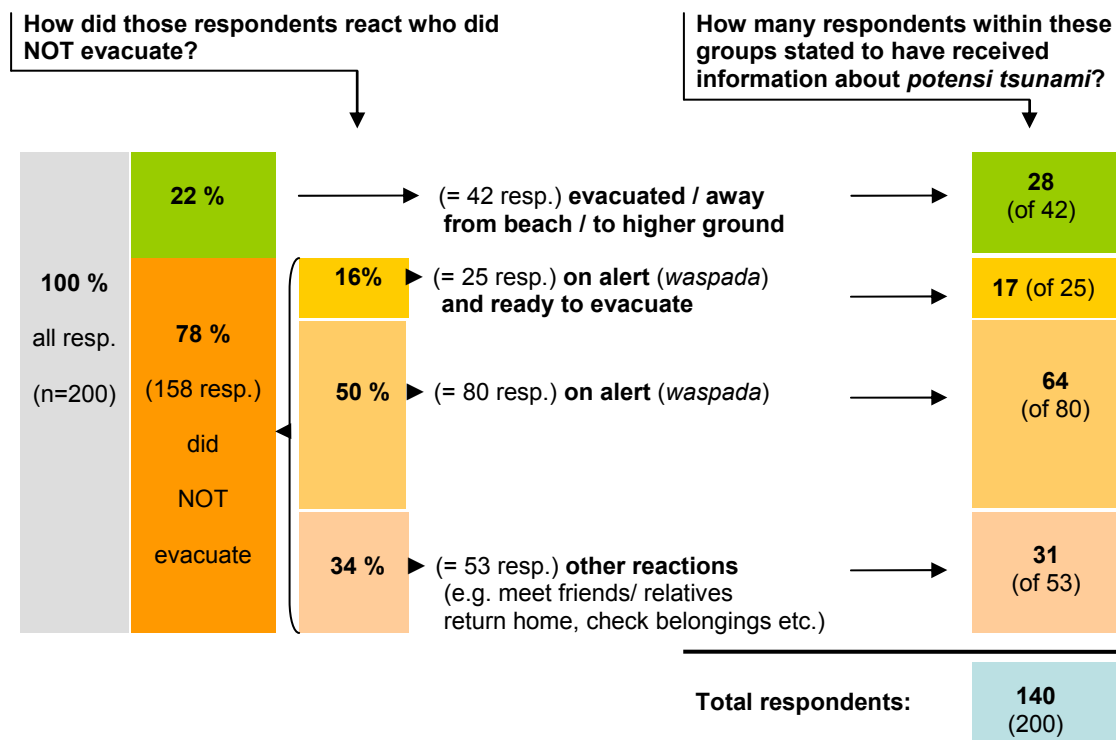


Figure 9: Actions of those respondents who did NOT evacuate, go away from beach/ to higher ground and reception of information on potential tsunami in the respective sub groups.

These six cases only describe the behaviour of a small fraction of respondents who reacted with evacuation to a potential tsunami threat—with considerably varying reaction time. The majority of respondents were far from reacting with evacuation to the potential arrival of a tsunami wave at the coastline of Padang City.

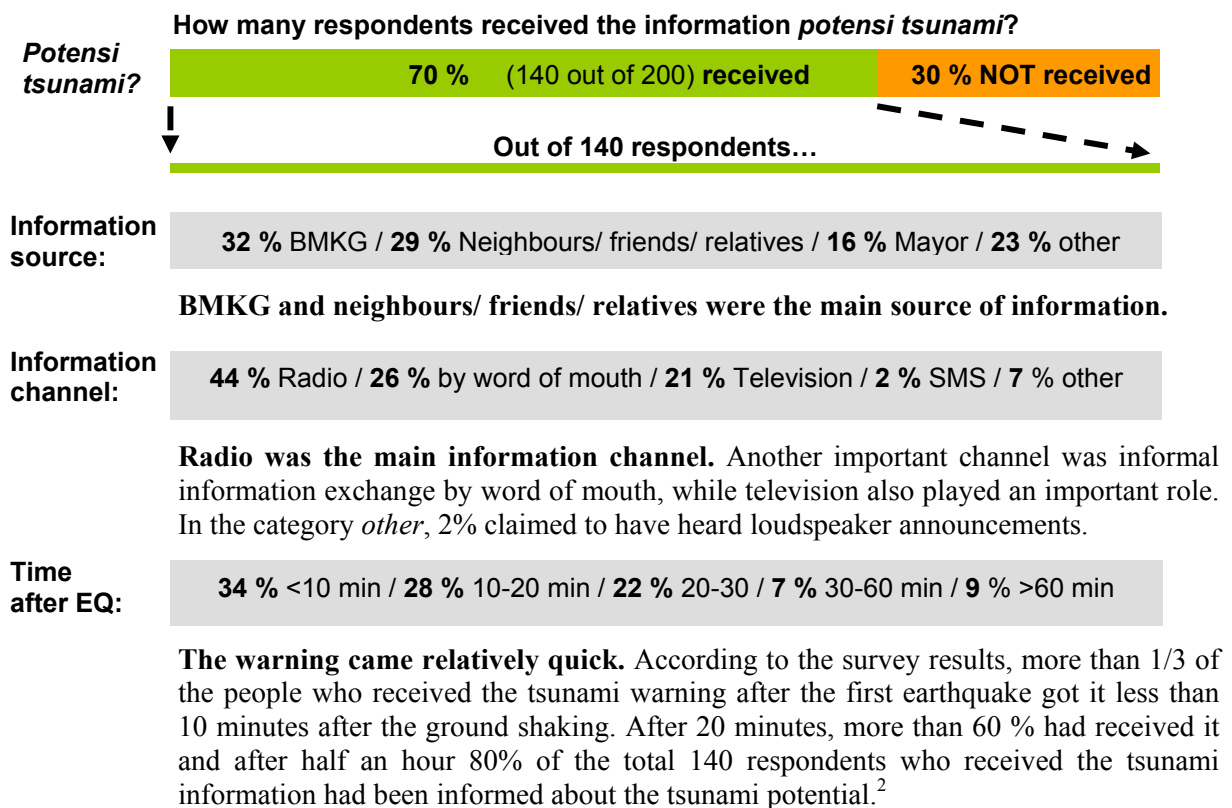
What did those respondents do who did NOT perform any kind of evacuation action?

The following looks at the group of respondents who did NOT evacuate nor went away from the beach/ to higher ground at any time after the first earthquake (78 %, see figure 9). The major reaction of respondents in this group was to “stay on alert” (*waspada*). This answer was given by half of those who did not perform any evacuation action. Another 16 % within this group stated to have been “on alert and ready for evacuation” which they, however, never put into action. Finally, the remaining 34 % represent respondents who showed other reactions, e.g. returning home to check belongings; meet friends, relatives and neighbours.

B. INFORMATION ABOUT TSUNAMI POTENTIAL

In total, 70 % of all respondents reported to have received the information *potensi tsunami*. The right column of figure 9 shows that in each of the respective sub groups more than half of the respondents received the information about a potential tsunami. This is the case for those who evacuated/ went away from beach/ to higher ground, those who stayed on alert/ stayed on alert and were ready for evacuation as well as those respondents who performed other reactions.

Figure 10: Reception of information about potential tsunami – source, channel, timing, perceived content.



² Any data related to time has to be handled with care since it appears difficult for anyone to recall exact timing more than a month after the event.

Perceived content:

64 % *potensi tsunami* / 21 % *potensi tsunami: be on alert* / 7 % *potensi tsunami: evacuate* / 3 % *potensi tsunami: go to safe area* / 5 % other

The majority only “heard” potential for tsunami but no additional guidance for evacuation. More than half of the respondents stated that they had only received information about a potential tsunami (*potensi tsunami*). About 1/5 reported that they received additional information saying that they should be on alert (*waspada*). Only 7% “heard” evacuation guidance while 3% understood that they should move to a safe area.

Comparing the reception of tsunami information across the different sub groups, there seems to be no significant link between the reception of information and respondent reactions. The majority of respondents (in each sub-group as well as in total) received information about a potential tsunami. However, this information did not trigger a consistent reaction among the people interviewed during this survey.

Reception of the information *potensi tsunami* – what was its source, channel, timing, and perceived content?

Figure 10 presents the results on information source and channel, displays the time it took to receive the information and shows how the message content was perceived by the respondents. The warning came relatively quick. Radio, informal networks and TV were the main channels for warning reception and over half of respondents stated BMKG and friends and relatives as their source of information. The results regarding the perceived content of the information reveal that 85 % of respondents stated to have received information saying that there is a potential tsunami threat (*potensi tsunami*). Within this group 21 % of respondents additionally “heard” that they should stay on alert.

3. CONCLUSIONS

Only 22 % of the people interviewed in this survey reacted to the earthquake and information about a potential tsunami threat with evacuation/ moving away from the beach or to higher ground. Of those who moved, the majority did not evacuate in a timely manner—considering the limited time for reaction with regards to a local tsunami threat.

This indicates that the assumption that people would start evacuation on their own initiative directly after strong ground shaking proves not to be true.

Overall, the information about a potential tsunami quickly reached the respondents in the “red zone” of Padang City and was mainly received via radio, by word of mouth within informal networks and television. The content of the information, however, varied significantly.

Although the information about a potential tsunami threat (*potensi tsunami*) reached 70 % of respondents, most of them only “stayed on alert” as they did not perceive the received message as a call to take further action for evacuation. **This confirms that warning without clear guidance does not trigger a consistent reaction.**

There are various reasons why respondents did not react in an appropriate way to ground shaking and information about a potential tsunami threat:

1. Many people only received the BMKG warning message via public TV / Radio / SMS or by word of mouth from friends, relatives and neighbours. BMKG warning messages do

not provide any guidance nor suggestions or recommendations from official sources on how people should interpret the message and react.

2. The current BMKG warning scheme does not give any information about potentially affected coastal areas and the expected magnitude of the impact. This results in a high level of uncertainty for the people at risk who have to decide whether to evacuate or not.
3. The BMKG warning was not perceived as information about an imminent threat which requires immediate reaction. The wording *potensi tsunami* used by BMKG is correct from a factual or scientific point of view (as a tsunami occurrence is still not confirmed) but is apparently perceived by most people as information that still needs to be confirmed before taking further action.

Only a minority of the respondents received information from local authorities. As only few people “heard” evacuation guidance and understood they should move to a safe area, the questions arise whether (1) warning and guidance messages issued by local authorities are comprehensible and clear, and, whether (2) people at risk in Padang are familiar with those messages and know how to react once a warning and guidance message has been issued.