Proceedings of the International Symposium on Engineering Lessons Learned from
the 2011 Great East Japan Earthquake, March 1-4, 2012, Tokyo, Japan

TOWARDS BETTER MITIGATION OF TSUNAMI DISASTER IN INDONESIA

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ABSTRACT: This paper describes the tsunami disaster mitigation development in Indonesia, especially related to its basic framework, its implementation and response to tsunami disaster happened after 2004. The potential of tsunami intensity as hazard identifier is also discussed. Lesson learnt from the two recent tsunami events, i.e. Southern-West Java tsunami 2006 and Mentawai tsunami 2010 will be used to discuss about the significant role of land use management as well as education, training and drill in the reduction of fatalities during tsunami disaster.

Key Words: Indonesia, tsunami disaster mitigation, emergency communication and transportation, tsunami danger and precursor knowledge, maintenance of tsunami early warning system, preparedness

INTRODUCTION

Historical data on tsunami disaster indicate that Indonesia is the most tsunami vulnerable country in the world. In total, 110 fatal tsunamis occurred in Indonesia during 1600-2011, which caused casualties and have killed about 244,000 people in total. This total human toll is unfortunately so far the highest in the world, which indicates the high level of vulnerability of Indonesia against tsunami. Consequently, serious effort towards effective tsunami disaster mitigation in Indonesia is urgent. Figure 1 shows the big-six countries or region with the highest total human casualties due to tsunami disasters within the years of 1600-2011 (ITDB, 2006; Watanabe, 1985; NAO, 2004).

The huge disasters by the 2004 Indian Ocean Tsunami (IOT) that threaten countries surrounding Indian Ocean stimulated the world cooperation in the development of Indian Ocean Tsunami Early Warning System (IOTEWS). At the same time countries around Indian Ocean, including Indonesia, have been impelled to develop or enhance their disaster management system.

The fundamental revolution on disaster management paradigm in Indonesia was officially started after the enactment of Disaster Management Law in 2007. This law clearly mentions that disaster

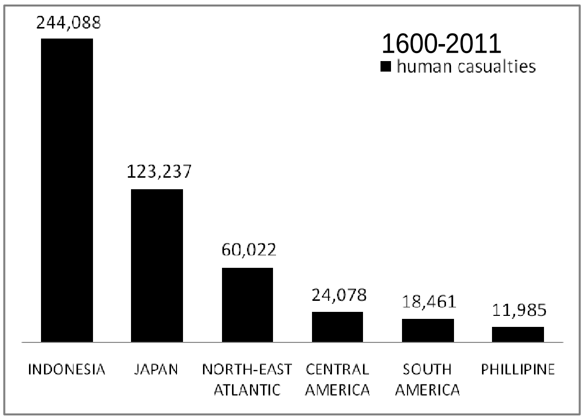


Fig.1 The big-six countries or region with the highest total human casualties due to tsunami disasters within the years of 1600-2011 (ITDB, 2006; Watanabe, 1985; NAO, 2004).

management includes all three phases of disaster, i.e. before disaster (preparedness), immediate-response actions during and after disaster (emergency), and after disaster (recovery and reconstruction).

In the Indonesian Disaster Management Law 2007, disaster mitigation is classified to be the measure before disaster and includes the activities of (a) land use management, (b) development planning, infrastructure development, building code, and (c) education, training and drill. Implementation of these activities required knowledge of risk including risk mapping. To provide accurate information about the risk, understanding about hazard characteristics is the prime requirement.

In the simplest approach, the tsunami hazard maps were drawn based on the historical data of tsunami wave height available for each area, which is finally classified into high – medium – low tsunami hazard area. However, such a hazard map may not fully provide the necessary information because the actual disaster is not merely dependent on wave height but are also affected by local topography, demography, landuse, etc. Disaster mitigation planning needs more specific information to enable detail action. In this concern, this paper is trying to provide hazard identification by using tsunami intensity, based on which disaster mitigation activities can be determined easier.

Lesson learnt from the two recent tsunami events, i.e. Southern-West Java tsunami 2006 and Mentawai tsunami 2010 will be used to discuss about the significant role of land use management as well as education, training and drill in the reduction of fatalities during tsunami disaster.

POTENTIAL OF TSUNAMI HAZARD IN INDONESIA

Hamzah et.al (2000) divided Indonesia into 6 zones (see Fig.2) by considering the composition of its tectonic plate-convergence, the depth of seismicity variation, and the characteristics of tsunami generation. It is described that in Zone-A most of tsunamis were generated by earthquakes as results of the activities of two tectonic elements; (i) subduction of Indian Ocean Plate beneath the Eurasian Plate and (ii) the great Sumatera fault located in Sumatera from its southernmost part near the Sunda Strait to its northernmost part near the Andaman Island. Two tsunamis were generated by volcanic eruption of Krakatau in 1883 and 1928.

In Zone-B, tsunamis were generated by two types of earthquake, i.e. subduction of Indian Ocean Plate beneath the Eurasian Plate and back-arc- thrusting lies east-west in the north of the Bali-Lombok-Sumbawa Islands. One volcanic tsunami was caused by the eruption of Tambora in 1915.

In Zone-C, all tsunamis were caused by tectonic earthquake due subduction of the Australian Plate beneath the southeastern part of the Eurasian Plate except two by volcanic eruption of Rokatenda in 1927 and 1928 and one tsunami by landslide at Lomblen.

In Zone-D all tsunamis were generated by earthquakes in the back-arc opening zone in the Makassar Strait, in which earthquakes usually have normal fault mechanism.

In Zone-E, within all tsunamis, four tsunamis were generated by volcanic eruptions, i.e. Awu in 1856 and 1892, Ruang in 1889, and Gamalama in 1871. The remaining tsunamis were generated by earthquakes in the Molucca Sea collision zone.

In Zone-F, tsunamis were generated by shallow earthquakes associated with the activity of Caroline subduction zone.

Based on the tsunami data provided by International Tsunami Data Base (WinITDB) developed by Gusiakov et.al (2006), Hamzah et.al (2000), Widjo et.al (2006) and Hidayat et.al (2007) a decadal tsunami events statistic in Indonesia was drawn. In Fig.3, these data are shown as bar graphs corresponding to each zone (A, B, C, D, E, and F) marked in Fig.2.

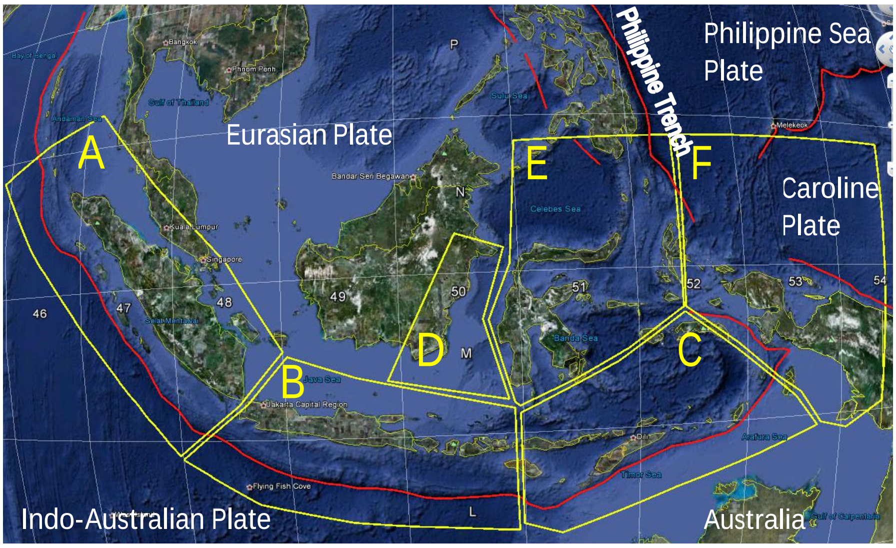


Fig.2 Seismotectonics zonation of Indonesia Region, which is divided into six zones (Zone-A, B, C, D, E, and F). Yellow lines denote the boundaries of each zone. (Source: Hamzah et al., 2000)

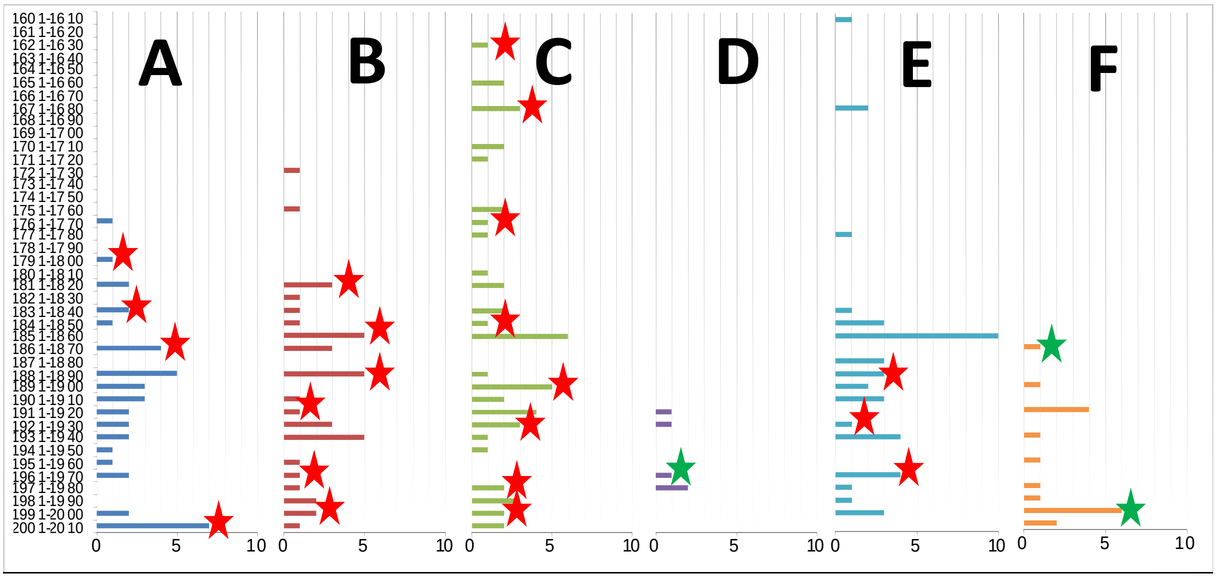


Fig.3 Decadal tsunami event statistics in Indonesia based on ITDB data (Gusiakov et.al. 2006) plus the latest data. Red-stars mean tsunami with I $\geq$ 2.5 or those caused significant fatalities, whereas green-stars indicate tsunami with I $\leq$ 2.5 but caused considerable fatalities in the area.

In Zone-A, very few records are available on tsunami wave height or fatalities except after the 2004. However, it could be noticed that the recurrence of tsunami with intensity of 2.5 or higher is learned to be happened about every 100 to 150 years. The following events were reported to cause high Tsunami Intensity (I) or cause big fatalities (F) or damage, i.e. in 1797 (I=3), 1833 (I=2.5), 1861 (I=3, F=725), and 2004 (I=4, F=165,000).

In Zone-B, the recurrence of tsunami with intensity of 2.5 or higher is about every 30 to 50 years. The following events are considered to have significant level of hazard or disaster, i.e. 1818 (I=3.5, F=400), 1851 (Hmax=14.5), 1883 (Hmax=36, I=4.5, F=36,417), 1917 (F=15,000), 1977 (I=3.5, F=189), 1994 (I=2.5, F=250), and 2006 (I=2, F=390).

Zona-C is the most active tsunami zone with the long record since 1629. It is seen that tsunamis with intensity of 2.5 or higher have happened about every 50 to 80 years. They were including the events of 1629 (I=3), 1674 (I=4, F=2,970), 1763 (I=2.5), 1852 (I=2.5), 1899 (I=3), 1928 (I=3), 1979 (I=3, F=539), and 1992 (I=2.7, F=2,200).

Zone-D is the most less tsunami hazard area in Indonesia. Only five tsunami events were reported since 1917 and the tsunami intensities I are less than 1.5. However, fatalities of 13 people were reported in the event of 1967.

In Zone-E, the recurrence of tsunami with intensity of 2.5 or higher is about every 40 to 50 years. Although the fatalities were not as huge as those in Zone-A, B, or C, there were four records of tsunami events with tsunami intensity equal or greater than I=2.5, i.e. 1889 (I=2.5), 1927 (I=3, F=50), 1968 (I=3, F=392). In addition, in 1856, smaller tsunami with I=2 caused fatalities of F=100.

Zone-F booked more tsunami event comparing to Zone-D but the recorded maximum tsunami intensity are only between 1.5 and 2. The most fatal tsunami disasters in this area happened in 1864 (I=1.5, F=250) and 1996 (I=1.8, F=108).

Tsunami Intensity Variation in Indonesia

From the same source of data (Gusiakov, 2006), correlation of tsunami intensity with its incident number for each area was drawn as in Fig.4. The tsunami intensity scale is of Soloviev-Imamura (1972). It is shown that, except Zone-D and F, most of Indonesian region experienced tsunami hazards with high intensities of greater than I=4. In Zone-D and F the maximum tsunami intensity is only I=2. It can also be seen that in all area, the most frequent events are those with tsunami intensity between I=1 and 1.5.

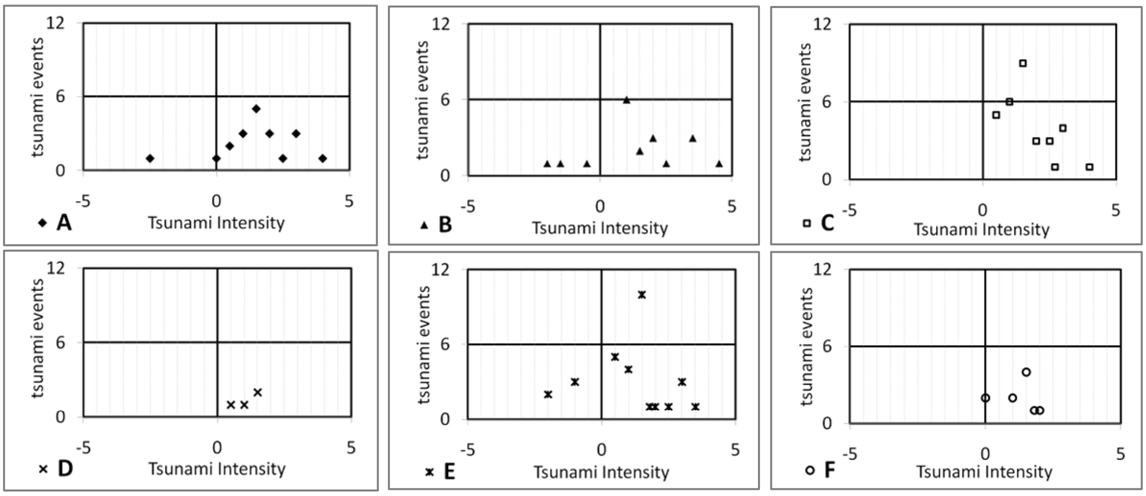


Fig.4 Correlation of tsunami intensity with its incident number for each area.

A rough approximation of the exceedence probability graphics of tsunami intensity were generated from the available data. Since the data in Zone-A, B and E show a similar tendency, the data of these zones are combined to get the graphic for the related zones and is provided in Fig.5(left). The similar graphic for the combined Zone-C and F is shown separately in Fig.5(right). No graphic is provided for Zone-D as the data for this zone is too few. From Fig.5 we learned that the median tsunami intensity in all zones are about I=1.5.

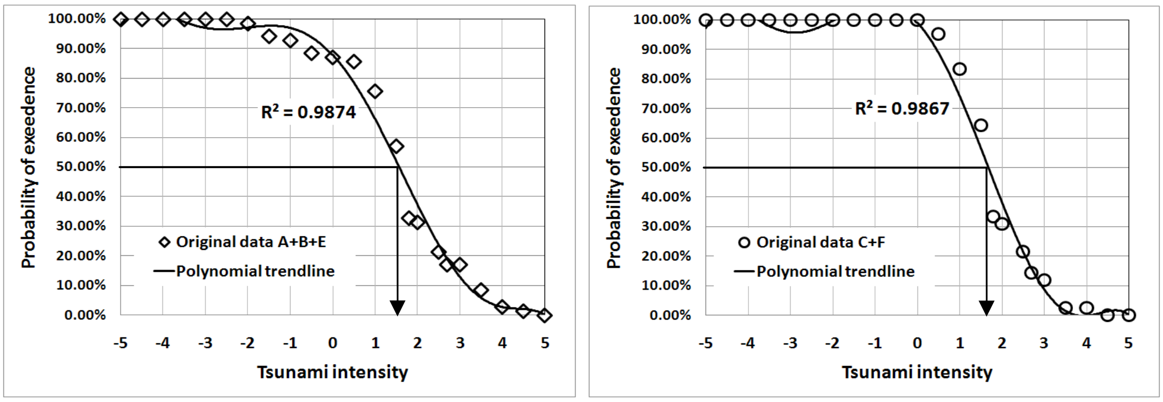


Fig.5 Graphics of probability of exceedence of tsunami intensity for: (left) zones of A+B+E; and (right) zones of C+F

Based on the above discussion, tsunami intensity I=1.5 (Soloviev-Imamura scale) shall be set-up as a threshold for minimum design criteria of any mitigation measure in all area of Indonesia, whereas the maximum design criteria is adjusted to the relevant area.

Typical Exposure and Vulnerability against Tsunami Disaster in Indonesia

The exposure of coastal area against tsunami shall be assessed by considering the distance of vital assets (residential area, factory, city infrastructures, etc.) to coastline, the altitude of the area above mean sea level, and availability of protective measure (Post, 2007). Whereas, population density, building structures, and building density have been considered as several important factors related to vulnerability.

Most of coastal cities or village in Indonesia traditionally lay very close to coastline without any protective structure against high wave. Many of them are also located along the river bank from the river mouth into inland direction. At several parts of coastal areas, seawall or revetment had been constructed but for the purpose of coastal erosion countermeasure only.

Further, referring to the description by McGranahan et al. (2006), 20% of Indonesian populations (about 40 millions) are living along coastal areas that fall under the criterion of Low Elevation Coastal Zone (LECZ). McGranahan et al. define the LECZ as contiguous land area up to 100 kilometers from the coast that is ten meters or below in elevation. This situation increases the exposure grade of Indonesian coastal areas against tsunami hazard.

Referring to Tsunami Hazard Map of Indonesia (Paris, 2007), the following areas are classified into very high and high tsunami hazard area: western-coast of Sumatera, from Banda Aceh to Lampung; west and southern coast of West-Java; southern-east coast of East-Java; northern coast of Bali, north-eastern coast of Flores and islands north to Timor Island; northern coast of Papua Island; western coast of Central Sulawesi; and coastal areas surrounding Halmahera Sea, Sulawesi Strait, and Seram Sea.

Figure-8(a) and -8(b) respectively show the Google's bird view of Padang City and Bengkulu City, the two most populated coastal cities along western-coast of Sumatera Island. These figures show high level exposure of those two cities against tsunami disaster by fact that these cities are linked to the sea without any protection at all. Refer to the map of population density within the LECZ provided by CIESIN (2007), Padang as well as Bengkulu cities are occupied by 500 to 1,000 residents within a kilometer square of its LECZ. According to Borerro's worst scenario simulation (2006), the future giant tsunami will inundate about 8 km coastline of Padang City up to 1.5 km inland, whereas about 11 km of Bengkulu City's coastline will be inundated between 400m to 1.5 km inland.

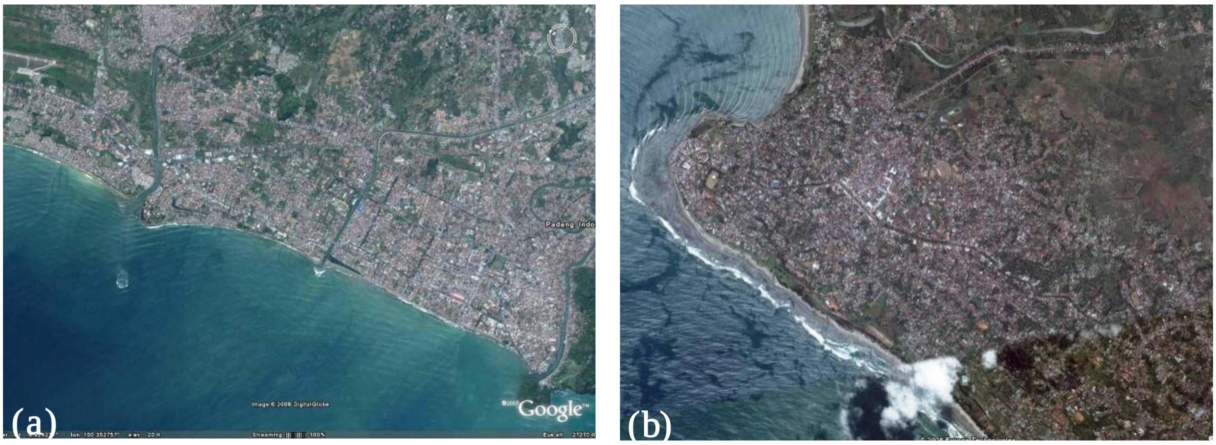


Fig.8 Google's bird view of (a) Padang City and (b) Bengkulu City, the two most populated coastal cities along western-coast of Sumatera Island.

TSUNAMI EVENTS IN INDONESIA AND IMMEDIATE EVACUATION RESPONSE

Systematic investigations on tsunami disasters in Indonesia were started just after the Flores Tsunami in 1992. This is the first devastating tsunami in the modern age of Indonesia with fatalities toll of about 2,200. Twenty-five tsunami events were reported happened in Indonesia since then, however, not all events caused casualties or fatalities, and some others were not recorded in detail. Table 2 shows tsunami events in Indonesia since the Flores Tsunami in 1992.

Table 2. Tsunami events in Indonesia 1992-2011

Year	Month	Date	Time	Lat	Long	Ms	I	Hmax	D	Fatal	WS	Zone
1992	12	12	13:29	-8.48	121.9	7.5	2.7	26.18	L	2200	TIB	C
1994	1	21	11:24	1.01	127.73	7.3	1.5	2	L		N/A	F
1994	2	15	17:07	-4.97	104.3	7					TIB	
1994	6	2	01:17	-10.48	112.83	7.2	2.5	13.9	L	250	TIB	B
1994	10	8	06:44	-1.26	127.98	6.8	1.5	3	M	1	TIB	F
1995	2	13	15:42	-1.32	127.44	6.8				0	TIB	
1995	5	14	11:33	-8.38	125.13	6.9	1.5	4	M	11	TIB	C
1996	1	1	16:05	0.73	119.93	7.7	1.8	3.43	M	24	TIB	E
1996	2	17	14:59	-0.89	136.95	8.1	1.8	7.68	M	108	RTW	F
1998	11	29	14:10	-2.07	124.89	7.6	1.5	2.7	N	0	RTW	E
2000	5	4	12:21	-1.11	123.57	7.5	1	5	S	0	TIB	E
2000	6	4	16:28	-4.72	102.09	8			N	0	TIB	
2000	6	18	14:44	13.8	97.45	7.8			N	0	NOW	
2002	9	13	22:28	13.04	93.07	6.7	0		N	0	TIB	
2002	10	10	19:50	-1.76	134.3	7.7	1	3	N	0	TIB	F
2004	11	11	21:26	-8.17	124.91	7.5	1	2	N	0		C
2004	12	26	7:58	3.32	95.85	9	4	15	L	165,000	NOW	A
2005	3	28	23:09	2.06	97.01	8.7	1.5	4	L		TIB	A
2005	4	10	11:14	-1.71	99.78	6.5	-2.5	0.4	N	0		A
2005	7	24	15:59	7.9	92.1	7.2					TIB	
2006	3	14	15:57	-3.6	127.21	6.6	2	5	L	3	TIB	C
2006	7	17	15:19	-9.33	107.27	7.7	2	2		390	LTW	B
2007	9	12	13:10	-4.52	101.37		3	3.9	S	0	LTW	A
2009	1	3	19:43	-0.408	132.89	7.7				0		
2010	10	25	14:42	-3.484	100.114	7.7	3.3	9	L	530	PTW	A

In Table 2, **Ms** is surface magnitude of the earthquake, **I** is tsunami intensity scale of Soloviev-Imamura, **Hmax** is the maximum observed run-up value, **D** is damage classification in general, **Fatal** is number of killed people, **WS** means whether a warning message was released or not. In the **WS** column, **NOW** - no warning was issued, **PTW** - Tsunami Warning issued by Pacific Tsunami Warning Center, **RTW** - Regional Tsunami Warning issued by PTWC for areas having no TWS, **LTW** - Local Tsunami Warning issued by regional or national TWC, **TIB** – Tsunami Information or Attention Bulletin issued by any agency, N/A - status unknown).

Among those events, 15 events (shaded line in Table 1) were selected and used to draw diagram as shown in Figure-6. It shows number of killed people, tsunami intensity, effective local warning status, status of immediate evacuation action, initial tsunami arrival time and its lead time after earthquake in each tsunami events.

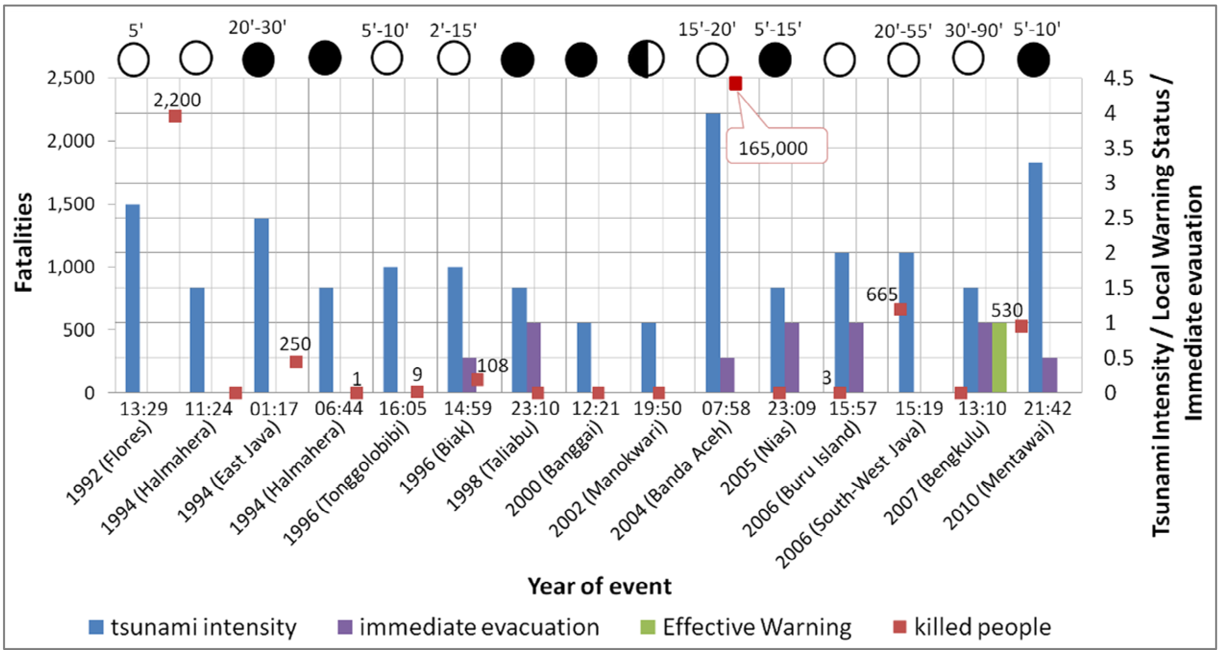


Fig.6 Number of killed people, tsunami intensity, effective local warning status, status of immediate evacuation, initial tsunami arrival time and its lead time after earthquake in 14 tsunami event in Indonesia within 1992-2011.

“Killed people” means number of people directly killled by the disaster. “Effective warning” means whether a local warning disseminated and reach to the residents effectively just before the disasters. If local warning was disseminated, then it is given the value of 1, whereas value of zero is given in case of no local warning at all. Meanwhile, “immediate evacuation” means whether the residents evacuated immediately after sensed the earthquake shaking. Value of zero means no evacuation, value of 0.5 means very few people were evacuated, and value of 1 is given to the events where many people immediately evacuated just after the earthquake or local warning.

Based on Figure-6, it is learnt that since 1992 only one local warning was effectively worked before tsunami disaster events (i.e. Bengkulu Tsunami, 2007).

Figure 6 also shows that immediate evacuations by most of the residents were conducting only in four events (with or without local warning, i.e. 1998, 2005, 2006, 2007), very few evacuation were in three events (without local warning, i.e. 1996, 2004, 2010) and the remaining events performed no immediate evacuation responses. This distribution is summarized in Figure-7.

It can also be seen in Fig.6 that immediate evacuation related to few or no fatalities due to tsunami. On the opposite, several to huge number of fatalities were recorded related to “no” or “very few” immediate evacuations. Although many other factors, such as coastal morphology, tsunami intensity, distance of residential area from the coastline, availability of coastal protection, etc. also have their roles however, these facts have given indication on the significance of immediate evacuation in reducing the fatalities due to tsunami disaster.

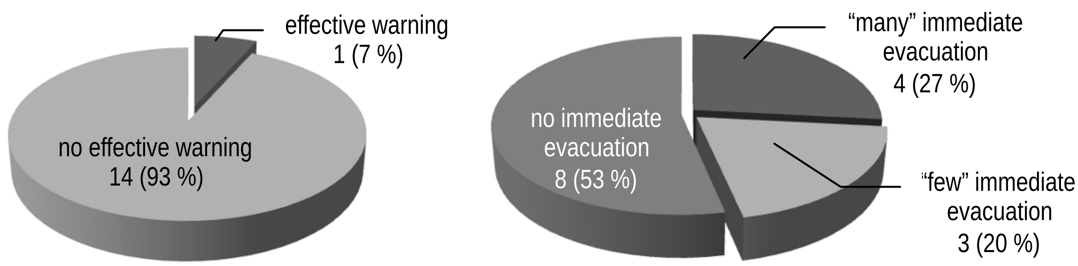


Fig.7 Distribution graphs of number of tsunami disaster events with or without local effective warning (left) and number of tsunami events with or without immediate evacuation response (right). Case of Indonesia (selected) 1992-2011.

At the top part of Fig.6, the dark circles sign for tsunami event between 21:00 to 07:00, empty circles sign for tsunami event between 07:00 to 18:00, and half-dark circles sign for the event between 18:00 to 21:00. The cases of Taliabu (1998) and Nias (2005) shows that people did immediate evacuation even if the hazard is generated in the midnight. It seems that their correct understanding on the danger of tsunami and high awareness have led them to perform effective response.

SOUTH-WEST JAVA TSUNAMI 2006, EFFECTIVE WARNING AND AWARENESS

A tsunami disaster was generated along the west and central southern coast of Java Island on 17 July 2006 due to a tsunami earthquake (M_w = 7.7) that occured offshore near the trench of the Sunda subduction zone south of Java at about 3:19 p.m. local time. The local felt reports indicated only weak shaking in Java. There was no ground motion damage from the earthquake, but there was extensive damage and loss of life from the tsunami (Mori et al., 2007). Figure 9 shows the map of the earthquake epicenter location (USGS, 2006).

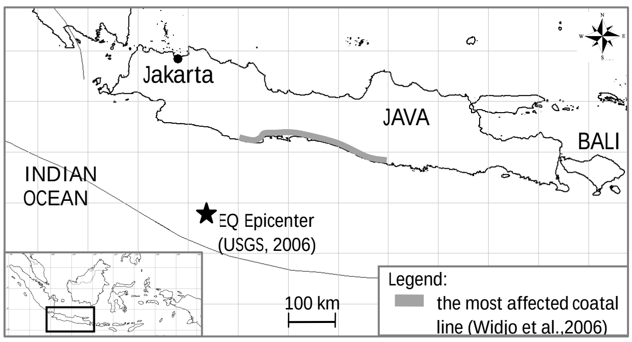


Fig.9 Map of the earthquake epicenter location

Despite having had learnt the great lesson from the IOT 2004, this disaster, however, still recorded 464 human tolls. The less awareness as well as less understanding of local community on the various types of tsunami precursor has caused this unexpected number of human toll.

There was no effective local tsunami warning system in place, whereas the national warning dissemination system had not ready yet. This caused the warning messages did not reach the target residents. This claim was supported by a questionaire based survey result reported by Muhari et al. (2007), which concluded that more than 70% of the residents in four locations among the five surveyed locations heard no evacuation warning related to this tsunami.Such a situation can be understood by refering to Table 2, which shows part of the warning time-line of South-West Java Tsunami of 2006 compiled by IOC-ITIC (2006). It is known from this record that initial detection of potential tsunami and warning initiatives were well performed by the Indonesian national authority. However, a failure to contact local government official by telephone due to unavailability of communication contact points at the respected coastal area is considered to have fluffed the effective early warning (see line no.6 in Table 1). This has taught the importance of ensuring warning dissemination link until the end node of disaster target. Regular updating of contact point data is comparably important measure to facilitate smooth warning dissemination.

Furthermore, the residents' knowledge on various types of earthquake characteristics and their possibility in generating tsunamis, such as this tsunami earthquake, which produced relatively weak ground motion shaking but generating tsunami, is indispensable. Otherwise, they may perform false response and causes high fatalities.

Table 1 Part of Timeline: July 17, 2006 Java, Indonesia Earthquake and Tsunami Compiled by IOC ITIC (Local time set was added by the author)

No.	UTC	Local	Elapsed Time	Action
1.	08:19	15:19	0:00	**Earthquake occurs** (USGS and Harvard CMT: 9.28S, 107.38E, 34 km, Mw7.7)
2.	08:21	15:21	0:02	**BMG calls start to be received**
3.	08:24	15:24	0:05	**BMG SMS alert** reporting automatic solution using 8 stations, **ML6.8**
4.	08:25	15:25	0:06	**BMG Mb5.5** => large difference in M implies non-typical earthquake. **PTWC Seismic Alarm** triggers alerting PTWC duty staff.
5.	08:26	15:26	0:07	**BMG press inquiry on phone and issued to media - caution for tsunami.** **JMA Operations Trigger for Distant Earthquake.**
6.	08:27	15:27	0:08	BMG unsuccessful to contact local government official in the coastal area by telephone due to unavailability of communication contact points at the said areas. SMS message sent to list of about 400 available addresses, though list did not contain many Java coastal addresses
7.	08:29	15:29	0:10	**NEIC Short Period Alarm**
8.	08:31	15:31	0:12	PTWC Observatory Message with preliminary epicenter (9.3S, 107.3E), magnitude (Mwp 7.3) and P-wave arrival times disseminated to other observatories (e.g., JMA, WC/ATWC)
9.	08:32	15:32	0:13	JMA receives PTWC Observatory Message
10.	08:33	15:33	0:14	WC/ATWC calls to PTWC (determines that WC/ATWC does not need to issue a bulletin since the earthquake is not in the Pacific Ocean)
11.	08:36	15:36	0:17	**PTWC Bulletin #1** - Indian Ocean Local Tsunami Watch Message disseminated via GTS, email, fax, putting Indonesia and Australia in a Watch, M 7.2; providing estimated tsunami arrival times for tsunami forecast points at Christmas Island, Australia (0836), Cilacap, Indonesia (0900) NEIC – initial automatic solution, Mwp 7.2
12.	08:38	15:38	0:19	JMA receives PTWC Bulletin #1
13.	08:39	15:39	0:20	PTWC confirms with Emergency Management Australia by Telephone
14.	08:40	15:40	0:21	**Tsunami arrival, Pangandaran**, ………………………………………………………..

MENTAWAI TSUNAMI 2010 AND DISASTER PREPAREDNESS FOR SMALL ISLANDS

Mentawai tsunami 2010 was generated by a tectonic earthquake (M_w=7.8) occurred on 25 October 2010 at 21:42 local time seaward of the Mentawai Islands, off-shore of Sumatra. Tsunami run-up of 3 to 9 m struck along southwestern coasts of the Pagai Islands and took 530 lives. Figure 10 shows location map of Mentawai Islands and the epicenter of the 2010 tsunamigenic earthquake.

Tsunami Mentawai on October 25, 2010 gaves another prove of the urgency of an effective telecommunication and transportation system during disaster, especially when dealing with remote islands like Mentawai. Unavailability of this system was considered as one of the root of the late emergency response in this disaster. The importance of integrated operation and maintenance of tsunami early warning system was also learnt from this disaster event.

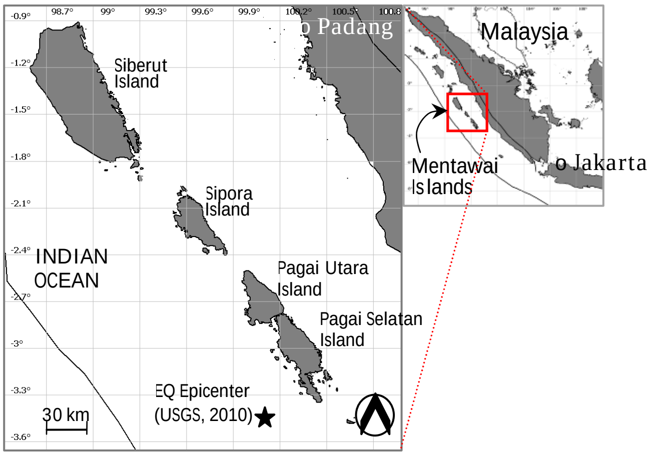
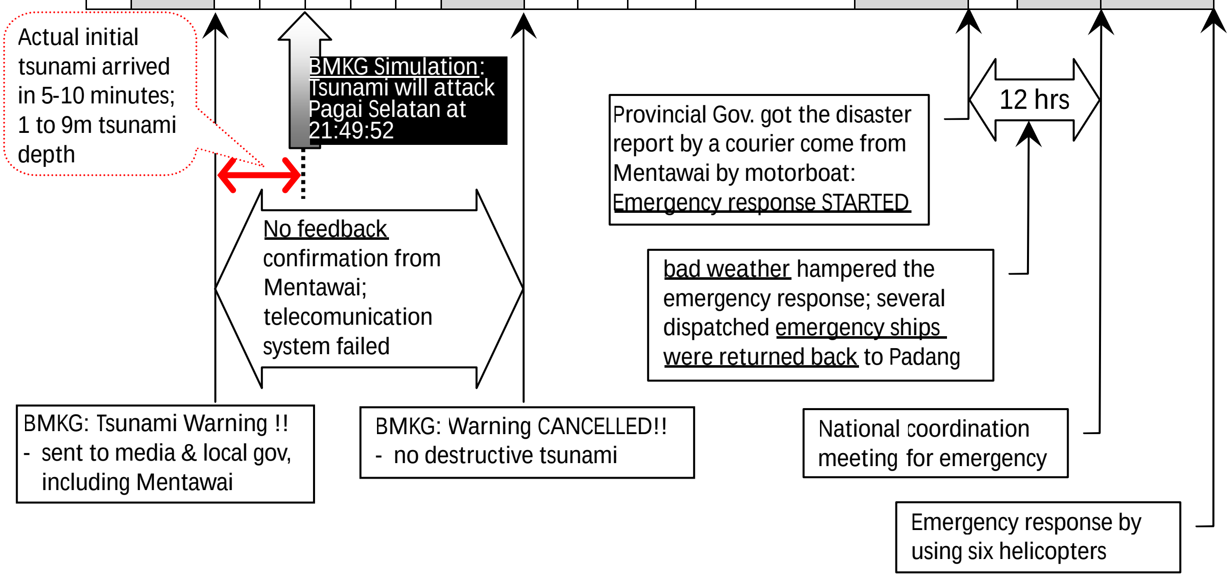


Fig.10 Map of the earthquake epicenter location

Table 3 Initial response timeline to the Mentawai tsunami

	10/25														10/26			10/27
LOCAL TIME	21:42	21:47	21:48	21:49	22:01	22:23	22:25	22:34	22:43	23:20	23:42	00:20	03:10	04:30	08:00		20:00	morning
TIME ELAPSED		5'	6'	7'	19'	41'	43'	52'	1hr 01'	1hr 38'	2hr 00'	2hr 38'	5hr 28'	6hr 48'	10hr 18'		22hr	34hr
	NEIC - EQ recorded		PTWC - EQ message	PTWC - tsunami watch	JMA - tsunami watch		BMKG - Enggano; 0.27m		BMKG - Padang; 0.3m	JMA - Padang; 0.3m	PTWC - tsunami watch cancelled	JMA – Padang, etc.; 0.2m – 0.4m						



Initial response timeline to Mentawai tsunami

In reference to the International Tsunami Alert Service Timeline released by UNESCO/IOC (2010), Mentawai earthquake and tsunami timeline by BMKG Indonesia (2010) and compiled internet online news, an initial response timeline to the Mentawai tsunami is summarized in Table 3.

Table 3 informs several facts related to the response situation at the initial state of Mentawai tsunami as follows:

1. Based on numerical simulation result, the Meteorological, Climatological and Geophysical Agency of Indonesia (BMKG) concluded that tsunami was generated and will attack Pagai Selatan Island at about 21:49:52. Accordingly, BMKG released tsunami warning 5 minutes after the earthquake through electronic media as well as direct message to the local governments including Mentawai. This warning was cancelled 47 minutes later since no feedback confirmation from the Mentawai local government about the actual field situation and tide-gage measurement network informed small tsunami amplitude (0.2 – 0.4m).

   It was known later that the telecommunication system failed to work since the electricity down due to the lack of fuel to feed the electric generator in the central telecomunication station. In fact, Mentawai Islands were regularly lack of fuel supply to support the daily activities.
2. The first courier from Mentawai Island arrived at Padang City in the next morning after 6 hours tough motorboat journey under the bad sea climate and weather to report about the disaster situation.
3. Immediately after receiving the actual disaster information, emergency responses were started by the Provincial Government of West Sumatera. However, severely bad sea climate and weather hampered the emergency response; several dispatched emergency ships were returned back to Padang;
4. A national level emergency coordination meeting was held in the evening of the same day to get decission on the mobilization of helicopters for supporting the emergency measures, but the actual actions were started only on the next day morning.

Risk Knowledge, Local Awareness and Fatalities Reduction

A field observation and questionaire survey were carried out in Mentawai Islands after the tsunami of October 25th, 2010. Field observation was done to investigate if land use management intervention regarding tsunami mitigation has been implemented, whereas questionaire survey was directed to collect information related to the evacuation processes, by using key questions such as background situation of evacuation decission, knowledge on tsunami, tsunami inundation depth at the initial decission of evacuation, ect. Survey locations include Surat Aban, Tapak, and Malakopa Villages in Pagai Selatan District, and Sabeugungung, Montei Teikaku, Montei Baru-baru, and Betumonga in Pagai Utara District.

Among the interesting result from the questionaire survey is that 40% of respondent have known about tsunami and its characteristics before the latest event, whereas 32% have never known before and 23% have heard about but not really understand. Regarding the timing of evacuation decission, about 49% respondent did just after sensed the earthquake, 20% did after heard the shouting for evacuation, 15% after seeing that other people runaway, and each are 5% after observing the sea water rise or recede respectively.

CONCLUSIONS

Tsunami intensity has a potential to be used as hazard identification based on which disaster mitigation activities can be determined easier.

In the near future, while continuing the development of the whole tsunami disaster mitigation system, the public education on the accurate knowledge of tsunami danger and various precursors must be intensively and extensively carried out, by which individual awareness as well as community preparedness can be sustainably developed in the whole tsunami prone area to minimize the impact of tsunami disaster.

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