Study of Possibility and Hazards Associated With Probable Tsunami Occurrence in Oman Sea

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Abstract
The earthquakes in Makran and Oman sea and the historical Tsunamies such as one that Happened on 27 November 1945 in Makran coast are main reasons for insecurity because of Tsunami's wave affected in the mentioned area. Also the geophysical interpretation supports This fact. The data of earthquakes were used in the current century and historical earthquakes to estimate the Gutenberg–Richter parameters and the earthquake cycle (recurrence intervals).
The tsunami in Indian Ocean generated after the Sumatra earthquake on 26 December 2004 provided wakeup call to the countries and people living near the coastal areas for advanced preparedness of tsunami related hazard.
The Iranian Makran coast with a length of about 500 km lies near the Makran subduction zone and is a susceptible area to the tsunamigenic waves. Although north-western Indian Ocean has experienced some deadly tsunamis in the past, this region remains one of the least studied regions in the world and little research work has been devoted to its tsunami hazard assessment.
The results of various studies show the existence of more than 10 m wave height at some locations near the coasts around Chabahar bay. Tsunamis are categorized as long waves; therefore, tsunami travel times can be computed using water depth as the only variable.

Introduction
The catastrophic devastation wrought by the tsunami occurred primarily in the Eastern part of the Indian Ocean (Indonesia, Thailand, Sri Lanka, and India). However, substantial damage was also documented in Somalia, where some 300 deaths were reported. In this respect, it became important to document any variability between the effects of the tsunami on various distant shores in Africa and Arabia in order to build a complete, homogeneous database of run-up and inundation parameters.
The latter can then serve as a benchmark for simulation models aimed at understanding the distal or local parameters controlling the development and amplification of waves at the beach. Oman is located in the Middle East, bordering the Arabian Sea, the Gulf of Oman and the Persian Gulf. It is slightly smaller than the state of Kansas. It is located in geographic coordinates of: 21° 00 N, 57° 00 E and the elevations are: Lowest Point: Arabian Sea 0 m Highest Point: Jabal Shams 2,980 m.
Researchers from German University of Oman (GUtech) and RWTH Aachen University in Germany found evidence for a land-uplift along the Omani coast and past tsunami that may have occurred in the 20th century and earlier. Along the coast they discovered isolated rocks of more than 20 tons that have been moved by sea waves. They are sure that these blocks were not moved by hurricanes that affected the coastlines in the past years, therefore they expect that they are of tsunamigenic origin.
Makran subduction zone (MSZ) and Andaman-Nicobar-Sumatra Arc are two major important tsunamigenic zones in the Indian Ocean which have noticeable underwater seismic activities
For creating tsunamis. The MSZ as triggered the second deadliest tsunami in the Indian Ocean is an important source for large tsunamis, as we know from the magnitude 8.1 earthquake and Tsunami that occurred there in 1945 with a death toll of about 4000 people (Pararas and Carayannis, 2006).
Literature review
There are many documents based on historical reports and numerical modelling which show any tsunamis have been occurring with different sources until 1945 into the MSZ (Ambraseys and Melville, 2005). Heck (1947) prepared a list of global tsunamis generated from 479 BC to 1946, that some of them were related to tsunami occurrences in the Arabian Sea and Adjacent regions. Berninghausen (1966) gathered another list of tsunami including 27 tsunamis reported from regions neighbouring the Indian Ocean which only three events were from the west coast of India and the Arabian Sea. As an important tsunami capacity, Page (1979) presented evidence for the recurrence of large-magnitude earthquakes along the MSZ and predict the 1945-type earthquake can occur every about 150–250 years in eastern Makran. Ambraseys and Melville (1982) studied historical earthquakes in Iran. Other list compiled by Murty and Rafiq (1991) used a variety of sources in the Indian Ocean region from 326 BC to 1974. Byrne et al. (1992) studied great thrust earthquakes along the plate boundary of the MSZ. Threshold tsunami generation potential was studied by Pararas-Carayannis (2006) along the MSZ. There are many different ways for studying tsunami, such as using pale-tsunami data, historical tsunami recorded reports, online DART systems, local tide gages and numerical modelling. In point of view tsunami behaviour after occurrence, tsunami simulation using historical data and numerical modelling due to low cost, is still common. Numerical modelling of tsunami is very important for understanding past events and simulating future ones. Determination of the potential run-ups and inundation by using Numerical modelling from a local or distant tsunami is recognized as useful and important tool, since data from past events are usually insufficient (Rafi and Mahmood, 2010).

The Makran Subduction Zone (MSZ) of the coast of Iran and Pakistan is a part of an accretionary wedge of late Cretaceous to Holocene sediments (Arthurton et al., 1982). The MSZ is a tsunamigenic narrow region due to reconstruction among three tectonic Eurasian, Indian and Arabian plates (Figure 1) which extends east from the Strait of Hormuz at the end of Zindan-Minab fault in south of Iran to the Ornach-Nal fault near Karachi in Pakistan with the length of about 900 km (Heidarzadeh et al., 2008).

![Figure 1. Tectonic feature and major earthquakes location of northern continent part of Indian Ocean.](image)

According to other subduction rate of subduction zones, MSZ is a relatively slow moving subduction zone. In point of view of seismicity, MSZ demonstrates that large and shallow earthquakes are common in this region which can be regarded as evidence for tsunami generation potential with approximately average return period 100–250 years of magnitude order of 8+ earthquakes (Heidarzadeh et al., 2008).
Importance and necessity of tsunami hazard management

Following the massive Indian Ocean tsunami in December 2004 and threatened to more than 225,000 human live and leaving at least a million homeless (Geist and Titov, 2006) was cause more serious attention to this phenomenon in assessing the risks of vulnerability on different coasts around the world, especially for marginal Indian Ocean countries. Definitely, Indonesian’s powerful tsunami in 2004 is not the first one in the region.

Although several tsunamis is occurring in the Indian Ocean region, the most recent full-size predecessor to the 2004 tsunami occurred about 550–700 years ago (Jankaew et al., 2008).

Tsunami hazard assessment in any particular region and its irreparable losses requires compilation and analysis of the past tsunami records. Better understanding of the tsunami on any region will be effect on the development of urban activities and also to estimate losses caused by criminal and financial of such events (Heidarzadeh et al., 2008). Therefore, studies the history of tsunami occurrence in coastal vulnerability around the world is collected and catalogued.

Several scientists around the globe investigated this particular tsunami and proposed simulation and related activities. For the Pacific Ocean rim countries, beside their own warning centers, there is advanced and well equipped international tsunami warning center, Explicitly, Pacific Tsunami Warning Center (PTWC) established in 1949. Besides, many countries, for example Japan, are equipped with up- to-date hazard maps, and warning & advisories services. Subsequent to the occurrence of the 2004 Indonesian tsunami, nations like India and Oman, as well as the United Nations Educational, Scientific and Cultural Organization (UNESCO), initiated setting up an Indian Ocean tsunami warning system. It is required that any tsunami mitigation by the Sultanate of Oman should focus on its eastern coastline. Given that the Oman is a coastal country, with the vast majority of its population and industry along its coasts, the importance of developing and maintaining a tsunami warning system should be evident, especially on the eastern coast. In conjunction with the tsunami warning system, sea floor earthquake monitoring program would also assist in detecting potential tsunami-generating events in the region.
Some suggestions for reducing and hazard managing of tsunami damage

The geography and geomorphology of the Sea of Oman, especially its shallow depth and lack of historical tsunamis are interpreted to mean that a tsunami in the Sea of Oman is very unlikely. On the other hand, experts articulate that Oman cannot overlook tsunami threat.

Studies show that the potential of the disaster knocking Oman’s eastern coast from the Makran subduction zone cannot be ruled out. Research work in Oman’s eastern coast near Qalhat and Sur on coastal evolution and ancient harbours found significant scientific evidence of the 1945 tsunami in Sur lagoon from shell deposits to raise possibility of tsunami striking Oman in future. Fractured shells deposits found in the area indicate the impact of tsunami or earthquake in the sea. Lastly, the public needs to be educated. In the past, this may have been difficult, but given the tremendous awareness raised by the 2004 Indonesian tsunami, the general public is far more likely to respond positively to the distribution of information by public signs at beaches seafronts or in the form of printed material. People who live in coastal settings should be given information on the risks of that environment.

Tsunami Analysis Aid GIS System in Japan, several robust Tsunami Analysis Aid Systems have been created and existing for preparing Geographic Information Systems (GIS) based tsunami hazard maps, which facilitate decision-making support to reduce tsunami damage.
By using such systems, it is possible to create tsunami hazard map for planning disaster prevention or to plan the location and height of civil infrastructures, which prevents tsunami disaster. By predicting possible tsunami scale and potential inundation areas, it is possible to establish suitable measures for reducing the damage in tangible form and in an easy-to-understand fashion. Similar measures have been developed, improved, and the results are published to the public in Japan regularly. The procedure of compiling a hazard map comprises: (1) establishing digital terrain model, (2) selecting possible earthquake, (3) performing tsunami simulation (estimating inundation area), and (4) creating tsunami hazard maps.
Considerations in creating a hazard map for Oman Land topography and bathymetry data are essential; future possible tsunami-generating earthquakes should be examined based on the latest scientific achievements, not only past tsunami or earthquake data. Social Conditions data (population, building, land use, etc.) are needed to establish an evacuation plan.

Figur 5- Susceptible lacate for Tsunami in south-earth of Iran

Contents to be included in Hazard map
- Inundation area to be used for identification of the vulnerable area or evacuation route, etc.; expected arrival time of tsunamis after the occurrence of the earthquakes; social information (such as schools, police stations, fire stations, medical centers, public facilities) for evacuation area, emergency countermeasures, etc.
- Publication, dissemination and education of hazard maps. The hazard maps should be shared among all-stakeholders. People should understand that the hazard information on the hazard map is not an actual situation in future, but a possible estimation. Education to the people is essential to make people use hazard maps properly. Local leader on disaster Management should be trained through “Training of Trainer” from central / local government to community levels. In order to establish the education frame work, a pilot project in a designated area could be considered to collect basic experiences and knowledge about how to implement “Training of Trainer” efficiently.

In Japan, sign boards based on tsunami hazard maps are erected all along the coastal regions where people live or frequently visit. Sign boards of evacuation routes, places for gathering (usually an elevated park or ground), tsunami height (maximum wave height based on past records), social information such as school, police station, fire station, medical centers, and public facilities can be noticed. Japanese people are perfectly educated on evacuation measures. Starting from primary schools to colleges, all the students and parents are educated about the hazard maps by specialists.
All the news network channels in Japan are well equipped, have ready to-respond to hazards expertise by which alert the public with actual happenings. For example once a tremor is felt, within a few seconds people can watch flash news of the tremor with relevant maps showing epicenter, the magnitude of the tremor and warning for any hazard. If the situation is worrisome, Japanese people know what to do subsequently. They keep exceedingly calm and wait for the authorities instructions. All the shops will be ready to supply food (there will be always a very polite queue in front of food shops). Hospital, fire and safety officers are perfectly placed to deliver their services. Conversely, if the epicenter of tsunamigenic earthquake is in close proximity to the coastal line, there is insufficient time for mass-evacuation which has happened in the March 11, 2011 disaster. Several free to use maps derived from advanced satellite images of the latest Sendai tsunami have been posted at http://www.pasco.co.jp/disaster_info/110311/. For the last 7 years, Dr. B. Babu Madhavan had been functioning in a variety of senior management roles at the rank of Director for the Tokyo based PASCO (world largest air survey corporation) and more recently as the President and CEO of its Indian operations. He has nearly 20 years’ experience in research suitable for Satellite and Airborne surveying industry.

Conclusion
Makran coasts are calculated. The Makran coast of Iran is exposed to the long waves generated in the Indian Ocean. The coast experienced long waves induced by tsunami during the past decades. Using the impact of the past events we present potential inundation areas for the great waves on the Makran coast. Results show that the Makran subduction zone can be the site of large earthquakes, as evidenced by the 1945 event. The tsunami reached Oman, and may have penetrated into the Persian Gulf. The final goal is tsunami damage reduction. To accomplish the goal, tsunami hazard maps should be connected with proper action and implementation of tsunami measures.
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