3rd Specialty Conference on Disaster Prevention and Mitigation
3e Conférence spécialisée sur la prévention et la mitigation des désastres naturels

Montréal, Québec
May 29 to June 1, 2013 / *29 mai au 1 juin 2013*

Coastal Impact of tsunami in industrial harbours: Study case of the Arzew - Mostaganem region (Western Coast of Algeria, North Africa).

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Abstract: In August 2007, 12 bathers were killed by a breaking wave on the beach of Mostaganem (Western Coast of Algeria). No earthquakes were recorded by the Algerian seismological network. Bathymetric surveys have mapped the evidence for submarine landslides in this region. In 1790, a tsunami triggered by a destructive earthquake in Oran affected the Alboran Sea. In this paper, we preview distinct tsunamogenic scenarios to examine the coastal impacts of tsunamis along Arzew Bay. Reports have indicated that hydrocarbon pollution is common along the Algerian coastline as a result of maritime oil traffic. In 1980, the oil tanker *Juan Antonio Lavalleja* spilled 280,000 tonnes of natural gas after striking a breakwater at the port of Arzew. Whatever are the uncertainties of a scenario triggering a tsunami (component of sea floor co-seismic deformation relative to sea slide component), the impact of sea waves in industrial harbors should be considered for environmental preservation purpose.

1 Introduction

Northern Algeria is located at the boundary between the Eurasia and African plates. The convergence between both plates leads to earthquakes, some potentially tsunamogenic, that reach magnitude greater than 6.5 Mw (Moment magnitude). Theilen-Willige (2006) indicate evidence of high energy waves and traces of tsunami flooding on the shoreline for the Arzew – Mostaganem region using Landsat ETM data, morphometric maps and GIS methodology. Historical information reveals the occurrence of sea level disturbances due to undersea earthquakes along the western coast of Algeria.

Table 1 below lists all the historical tsunami events for the Algeria coast (http://www.ngdc.noaa.gov/). A breaking tsunami wave hit the Arzew-Mostaganem region in August 2007, but this tsunami event is not recorded in any public scientific database and no seismological tremor was recorded by the Algerian Seismological National Institute. However, the European Mediterranean Seismological Center did record a magnitude 4.5 tremor at 21h26 GMT, centered at 0.05ºE, 36.24ºN (Figure 1). On that summer day, when people took advantage of the beach well into the evening, local newspapers reported that 12 bathers were killed.
The tsunami wave hit a single beach and no tsunami waves were recorded on the Balearic Islands gauges or along the southeast coast of Spain. No boats or other vessels and no coastal infrastructures were damaged on either side of the western Mediterranean. Hence, an assessment of the tsunami intensity for this event is very difficult to determine since the criteria from tsunami intensity scales are mostly applied to tsunami events with greater impact.

Table 1: List of tsunami events reported for northern Algeria from the NOAA-NGDC database (http://www.ngdc.noaa.gov/)

Latitude (ºN)	Longitude (ºE)	Date (dd.mm.year)
35.7	-0.6	09.10.1790
36.511	1.312	23.05.1857
36.571	1.903	15.01.1891
36.763	3.051	02.01.1365
36.763	3.051	06.05.1773
36.763	3.051	21.05.2003
36.767	3.477	21.05.2003
36.803	3.565	21.05.2003
36.91	3.91	06.05.1773
36.75	5.08	22.08.1856
36.8	5.767	22.08.1856
36.879	6.907	22.08.1856
36.9	7.767	22.08.1856

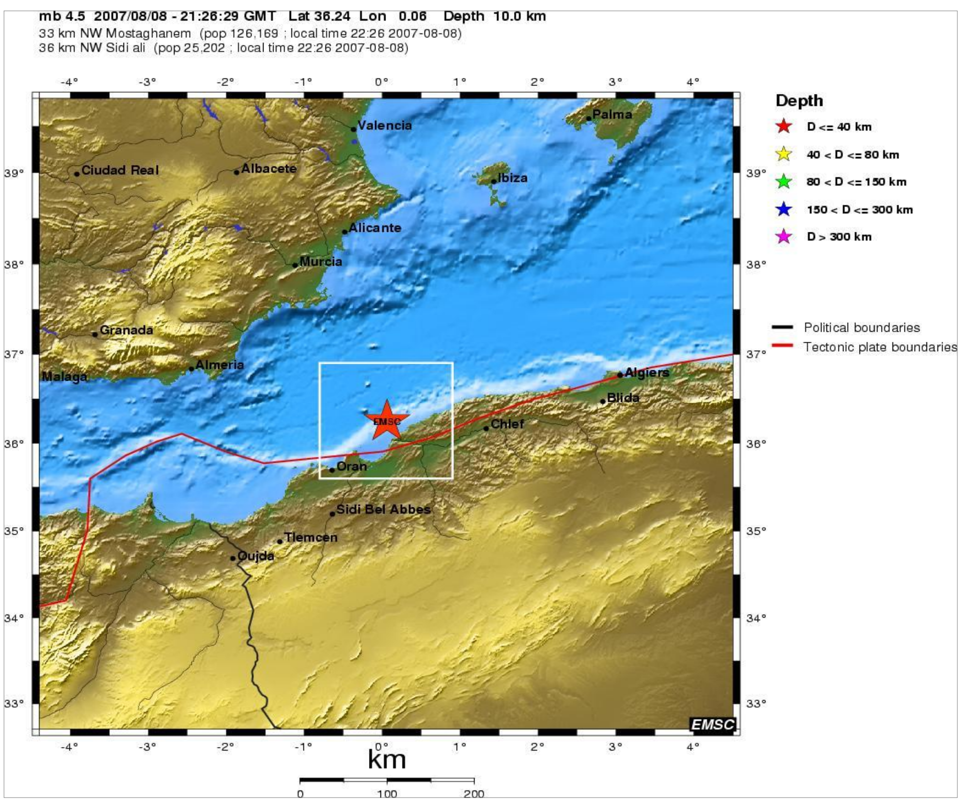

Figure 1: The 2007 tremor recorded by the EMSC (http://www.emsc-csem.org) considered to have triggered a tsunami wave at “Petit Port” beach in Mostaganem.

2 Objectives and Methodology

2.1 Objectives – Context of the study

The economy of Algeria relies mainly on the oil industry (75%). Oil refinery industries are located along the coast, in particular in Arzew (western Algeria) and in Skikda (eastern Algeria). These harbors have already been the location for oils spills events in the past, and the number of ships carrying oil has been reduced due to the risk of oil spills. Several pipelines have also been built in the western Mediterranean to better facilitate the transportation of natural gas (Medgaz, Trans Med) (Hayes, H. M., 2004). This region is also crossed by undersea communication cables that connect western and eastern Europe to Africa. Here, we focus on the effects of tsunami waves for the coastal area of Arzew.

2.2 Methodology : Review of tsunamogenic Scenario

Water flow energy and debris transported are among the potential sources of impact along the shoreline.
Energy and waves velocities are the parameters that best describe the level of damage. The scenarios reviewed in this study involve all sources that could induce a displacement of a body of water.
All calculations rely on classical hydrodynamic (Mader, 2004) and seismological empirical relations (Kanamori, 1983). The tsunami modeling was computed with the swan code (Mader, 2004) to consider all types of source areas. The topography used is from the ETOPO 1mn database (Amante and Eakins, 2009).
In this work, we focused on the 1790 earthquake epicentral area that triggered a tsunami and flooding observed up to south east of Spain (Lopez and Salord, 1990). We also considered the location of the 4.5mb tremor that induced a killer tsunami wave on the beach of Mostaganem in 2007. Today, offshore structures (canyons and escarpments) in western Algeria are well defined from echo-character mapping based on multibeam offshore surveys that took place in the last 10 years (Domzig et al., 2009). Hence we suggested different combinations for tsunamis sources that could affect the oil industry network and related environmental impact. Morphometric parameters to constrain the potential slides are crucial to select areas where landslide hazard can be identified (McAdoo, 1999). Mass Volume Displaced, headscarp heights and slide areas for slumping events are estimated from Dan et al. (2009) and McAdoo (1999). For each scenario, the delay between the onset of the earthquake and the associated slide is no more than 05 minutes. For simplification purpose, the distance between the epicenter and the onset of the slide is less than 10 km.

3 Results and discussion

The scenarios focused on the Oran - Arzew - Mostaganem region where hydrodynamic processes related to the Cheliff, the Macta and the Magoun rivers and mass movements triggered by the EQ shaking are hard to distinguish. Figure 2a below represents the energy for distinct tsunami sources. For the slumping event, the energies and velocities concern the sliding motion (kinetic slumping energy). The table 2 reports the corresponding shoreline impact and the potential failures within the oil industry network. The narrowness of the western Mediterranean continental shelf is another factor in the selection of the scenario when combining an EQ with submarine landslides. The high energy waves depicted by Theilen-Willige along the Arzew bay (2006) could be explained considering multiple tsunami sources. Slides thicknesses for existed identified structures with low to medium slope gradients are of primarily concern for slope instability issue. The 2007 tsunami is local and could be related to a sliding mechanism triggered by multiple sudden failures (slope gradients: 20˚ to 30˚) on the geological structures near the shoreline. The beach "Petit Port" is located only 05 to 15 km away from a series of small canyons oriented NE-SW, parallel to the coastline. The larger one is the Khadra Canyon (~10 km between the foot slope and the beach). Consequently, the submarine materials move straight forward toward the beaches.

Marine traffic is important and varies with time (Figure 2b). The failures of hydrocarbon infrastructures could produce water and soil pollution. The nearby ecosystem is vulnerable. A sebkha (salt flat) is located in the south of the Arzew Bay (“Les Salines d'Arzew”) (Figure 2b). It constitutes a habitat for migratory birds such as the pink flamingo. Weak layers increase the vulnerability for triggering slumps. Hence, the human activities and the man-made structures for the oil and industrial related constructions are to be considered for coastal environmental impact of tsunamis.

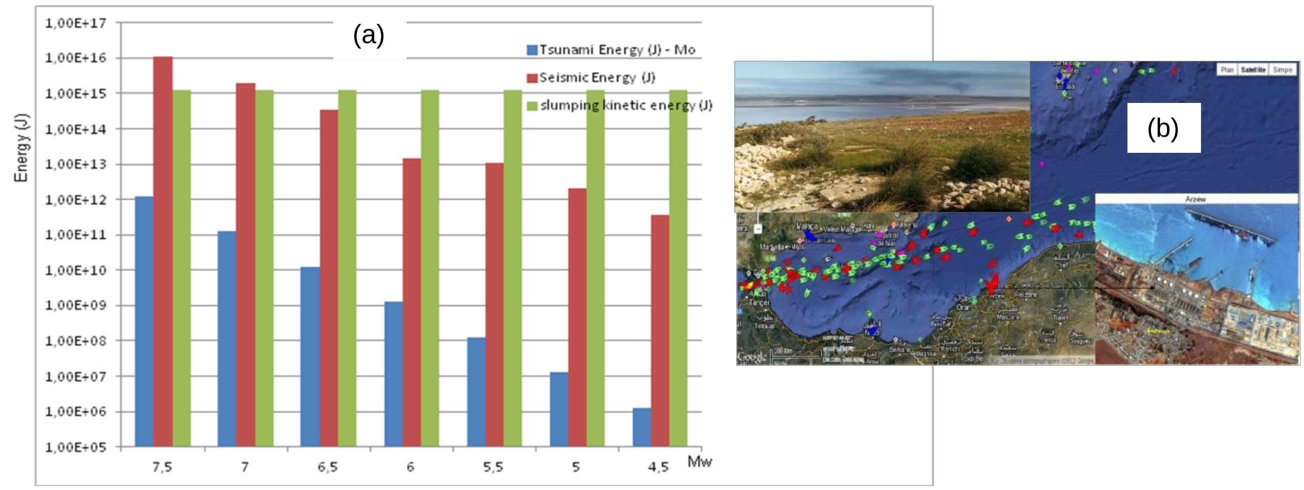

Figure 2: (a) Energies estimated for an EQ, a slump and a TNT-explosion (eq Mw); (b) Marine Traffic - 24.10.2012 (www.marinetraffic.com). Red & green arrows: tankers-vessels. *Inset: Right Bottom: Arzew harbour from www.asal2.dz; Left Top: Arzew Sebkha (Maxime Metcher, Wikimedia Commons).*

Table 2: Impact for tested scenario along the Oran – Arzew - Mostaganem region; TC: turbidity currents

Scenario	Point of Interest	Flooding	Man-Made structures
7.5 Mw + slide (0.8 km^3)	Arzew Harbour	+++; TC	cables + pipelines, Tankers/ Vessels
Slide (0.8 km^3)	“Moule” Canyon	+; TC	Tankers/ Vessels
4.5 mb + slide (0.8 km^3)	Beach Petit Port	+ ; TC	cables + pipelines, Tankers/ Vessels

Acknowledgments

We greatly thank Dr. Mader (Mader Consulting & Co) for his technical assistance with the SWAN code. Barbara Theilen-Willige is as well greatly acknowledged for her comments and constructive discussions.

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