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Challenges and Opportunities for Reducing Losses to Fast-Arriving Tsunamis in Remote Villages Along the Coast of Pakistan

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Additional information is available at the end of the chapter

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Abstract

Fishing villages in coastal Pakistan would need to respond quickly to escape a tsunami from nearby parts of the Makran Subduction Zone. A previous Makran tsunami, in 1945, took hundreds of lives in this coastal area. The majority of those fatalities took place along tidal creeks of the Indus Delta, where the parent earthquake was scarcely felt. Today, many of the Delta villages must be reached by boat, and telecommunication is difficult. These circumstances add to the challenge of their receiving timely warning of an incoming tsunami—whether it is the immediate natural warning from a felt earthquake or a subsequent official warning from government agencies. A study supported by Oxfam GB underscores this challenge. Ten remote coastal villages, each visited by the study team, were found to have limited links to official warning systems through landlines, mobile phones, and the Internet. Two cities, by contrast, have International Maritime Satellite Organization sirens that can be set off by satellite. In addition to technological solutions, partial remedies currently available include improved tsunami awareness, training about natural warnings, and land use informed by hazard assessments.

Keywords: coastal hazards, tsunami early warning, Pakistan, dissemination mechanism

1. Introduction

Recent events of cyclone (Gonu 2007 and Phet 2010) and tsunamis of Indonesia in 2004 and Japan in 2011 were the wakeup call for the scientific community and for developers, planners, and decision makers to prepare for a worst case scenario. Moreover, as a result of unplanned urban growth, negligence of construction standards, localized concentration of population and infrastructure, and the lack of awareness at the public and the institutional levels, coastal cities of developing countries are more vulnerable to the adverse effects of seismic hazards including tsunamis. Despite the tsunami's complex nature, its potential to create massive damage is compelling. Along coastal belt of Pakistan, many small fishing villages still lacking in basic communication infrastructure are extremely vulnerable to coastal hazards when personal notification is the only way of evacuation warnings. Most of these villages do not have landlines, electricity, roads, and mobile phone networks (**Figure 1**). Local conditions do not facilitate for any safe evacuation site nearby; details are discussed in Section 3.3.



Figure 1. View of Sonth Village, UC Basool, Tehsil Ormara, District Gwadar, Balochistan Province.

Historical evidence for tsunami along the shores of the Arabian Sea (Northern Indian Ocean) is rare and in cases contradicting. Out of several historical events the 1945 Makran earthquake is the only instrumentally recorded one that generated a tsunami. Therefore, the 1945 event serves as the basis for modeling approaches in early tsunami warning system which is currently being set up in Pakistan [1] (**Figure 2**).

National Tsunami and Cyclone Warning Center established at Pakistan Meteorological Department (PMD) [2] is being set up to watch, investigate, and warn about tsunami and cyclone threats to Pakistan coastline. The PMD established tsunami warning standard

operating procedures (SoPs) in 2010 [3] and has categorized tsunamis in different types based on the size and location of the parent earthquake.

A regional or local tsunami such as the one created in Arabian Sea in 1945 [3] might be more destructive for Pakistan's coastal belt than the one located farther in the Indian Ocean. Therefore, a dissemination of warning for local tsunami should be issued to the communities within 7–10 min of its origin, and usually, a possible threat of tsunami is proposed for an earthquake of magnitude 7.5 and above. A tsunami in the Indian Ocean might take as long as 10–13 h to reach and affect Pakistan's coastal areas. Henceforth, a warning for tsunami (as a possible threat) in this case is issued only if the earthquake magnitude lies within the ranges of 7.0 and above.

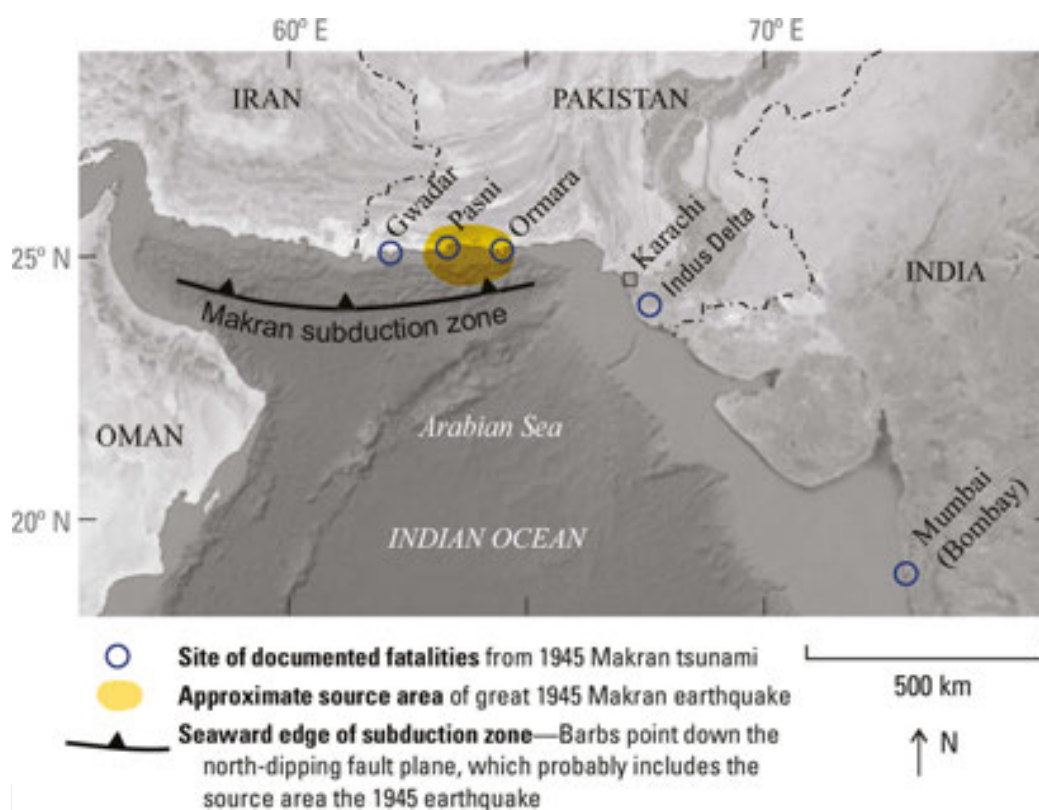


Figure 2. Makran and Indus Delta Creek region affected by 1945 Tsunami also covers communities studied.

This chapter analyzes the gaps in coastal hazard early warning system (EWS), specifically pertaining to dissemination of information along the coastal belt of Pakistan. Although EWS comprises of two components: (a) detection of threat and (b) subsequent relay of information, the chapter only focuses on the later.

This study sheds light on the challenges related to dissemination of early warnings of coastal hazards in Pakistan. It provides a comprehensive overview of the current arrangement for broadcasting a warning and limitations of the system (with references to sampled villages). The chapter also provides recommendations for division of responsibility and improvement of the system.

2. Methods

The study methods included desk review of the available documents and data on the subject, collection and analysis of primary and secondary sources data, and direct field observations as well as interviews with community's representatives and concerned personnel. All such information was finally summarized and put for analysis to identify issues and gaps, and to develop recommendations on effective early warning to coastal communities of Pakistan.

2.1. Primary data collection

Primary data collection is generally based on field survey comprising three main parts: (a) household interviews, (b) key informant interviews, and (c) focus group discussions.

The research team, led by the principal investigator, visited ten villages in Thatta, Sujawal, and Badin districts in Sindh and in the Gwadar district of Balochistan. The team was assisted by representatives of the communities for interpretation and to translate the questions and answers for both parties (**Figure 3**).



Figure 3. Discussion carried out with women at Sonth Village living at the bank of Basool River where it falls into sea.

2.1.1. Household interviews

A detailed questionnaires were designed for household interviews that focused primarily on the basic infrastructure related to early warning communication systems present in the communities, their efficacy in delivering information and warning the potential affectees in times of disaster (cyclones or tsunamis), and constraints or limitations observed in the operation of these early warning communication systems.

2.1.2. Key Informant interviews

For this part, the research team interviewed senior officials from various organizations namely WWF-Pakistan, Rural Community Development Council (RCDC) Gwadar, Trust for Conservation of Coastal Resources (TCCR) Sindh, Pakistan Meteorological Department, Pakistan Navy and the Government of Sindh. Their observations, suggestions, and recommendations pertaining to the gaps present in the currently employed early warning systems and consequently the required improvement have been incorporated in the chapter.

2.1.3. Focus group discussions

The questions concerning early warning system were mostly inquired from the middle- and old-aged men (mostly fishermen by occupation) and women of different households. A special emphasis was placed on the availability of various communication systems in the community and used at the household level. An additional content of the investigation involved recording oral histories of the 1945 tsunami. For this purpose, the researchers especially asked senior members of the household to recount what they had observed or heard from their elders witnessed the 1945 tsunami (**Figure 4**).



Figure 4. Focus Group Discussion at Tayyab Jatt village including interviewing eyewitness of 1945 Tsunami.

2.1.4. Compilation and analysis

The data set collected from site visits, key informant interviews, and focus group discussions was compiled in the form of report and was analyzed to draw conclusion on the present situation and provide recommendations for further steps needed to work on the elimination of gaps and limitations of the currently used early warning communication systems.

2.2. Secondary data collection

2.2.1. Desk review

A thorough desk-based review was conducted in order to carry out the project effectively. This comprises a literature review of reports drafted in the past that focuses on the same problem analysis, for example, Standard Operating Procedures of Tsunami Warning by National Seismic Monitoring and Tsunami Early Warning Centre Pakistan Meteorological Department 2010, Tsunami Risk Reduction for the Coastal Areas of Pakistan by National Disaster Management Authority, reports of UNDP's pioneer project on "Strengthening TEWS in Pakistan," UNESCO-IOC [5], Indian Ocean Tsunami Information Center (IOTIC) project website "1945 Makran Tsunami" and policy documents of government organizations to understand mission and objective of various stakeholders.

Data relating to the geography, topography, and demography of the target areas were collected from the Deputy Commissioner offices, WWF-Pakistan, Google imagery, and Survey of Pakistan's maps.

3. Current scenario

3.1. Institutional arrangement

The 2004 Indian Ocean tsunami and 2005 Kashmir earthquake prompted the Pakistani authorities to establish disaster management institutional arrangement and strengthening existing early warning system that could relay warning to those most at risk. Foregoing in view, in March 2010, the National Seismic Monitoring and Tsunami Early Warning Centre (NSM & TEWC) at Pakistan Meteorological Department (PMD) published Standard Operating Procedures (SOPs) for tsunami warning [4]. It identified PMD, disaster management authorities, and emergency responders as the key informants within the early warning communication chain that initiates from National Seismic Monitoring and Tsunami Early Warning Center (NSM & TEWS) at PMD and ends at the potential victims. This chapter assesses the institutional arrangements of each of the aforementioned authorities, especially in terms of capacity and limitations in two categories: Early Warning Dissemination Agencies and Emergency Responders.

3.1.1. Early warning dissemination agencies

3.1.1.1. Pakistan meteorological department

NSM & TEWC at PMD are adequately equipped to issue warnings depending upon National and Global Seismographic network's data on real-time basis to monitor seismic activity in order to locate potential tsunamigenic earthquakes. They are also connected with global centers such as Pacific Tsunami Warning Center (PTWC), Indian Ocean Tsunami Warning Centers (IOTWS), and Japan Meteorological Agency (JMA). PMD is also working on information sharing with

newly established tsunami early warning system at Oman for Arabian Sea. Once a warning is received, after initial assessment, PMD communicates a message to the district disaster management authorities.

PMD also has SOPs in place regarding the format of bulletin based on the category of threat, that is, time of issuance, level of threat, name of issuing agency, earthquake parameters (location, magnitude, and depth). These SoPs are the only time-based specific sequence of actions to be taken in case of potential tsunami threat among all stakeholders in Pakistan.

3.1.1.2. *Information flow*

PMD is acting as the key focal agency role. In case of tsunami all initial information flow will take place through PMD following timeline (**Figure 5**).

The information received to PMD about the possibility of a natural disaster such as tsunami, through national or international sources, is first conveyed to response agencies and national/provincial/district stakeholders within minutes, as per departmental SoPs.

- a. NDMA
- b. PDMA's (Balochistan and Sindh)
- c. District Coordination Officers (DCOs) Karachi, Gwadar, Lasbela, Thatta, Sajawal, and Badin
- d. Pakistan Army and Navy
- e. an Coast Guards
- f. Marine Security Agency
- g. Karachi Port Trust
- h. Gwadar Port Authority

PMD's usual modes of communication and dissemination of early warning information are:

- a. Automated GPRS-based SMS
- b. Mobile phone-based SMS (backup)
- c. Automated Fax-2 Channel
- d. Manual Fax-1 Channel
- e. Satellite Phone (limited recipients)
- f. Website updating www.pakmet.com.pk/ and email

In addition to the above-mentioned resources, PMD recently acquired mass notification system installed at Gwadar and Pasni cities connected via satellite.

Timeline for Earthquake Processing and Dissemination of Tsunami Bulletin for Makran Subduction Zone

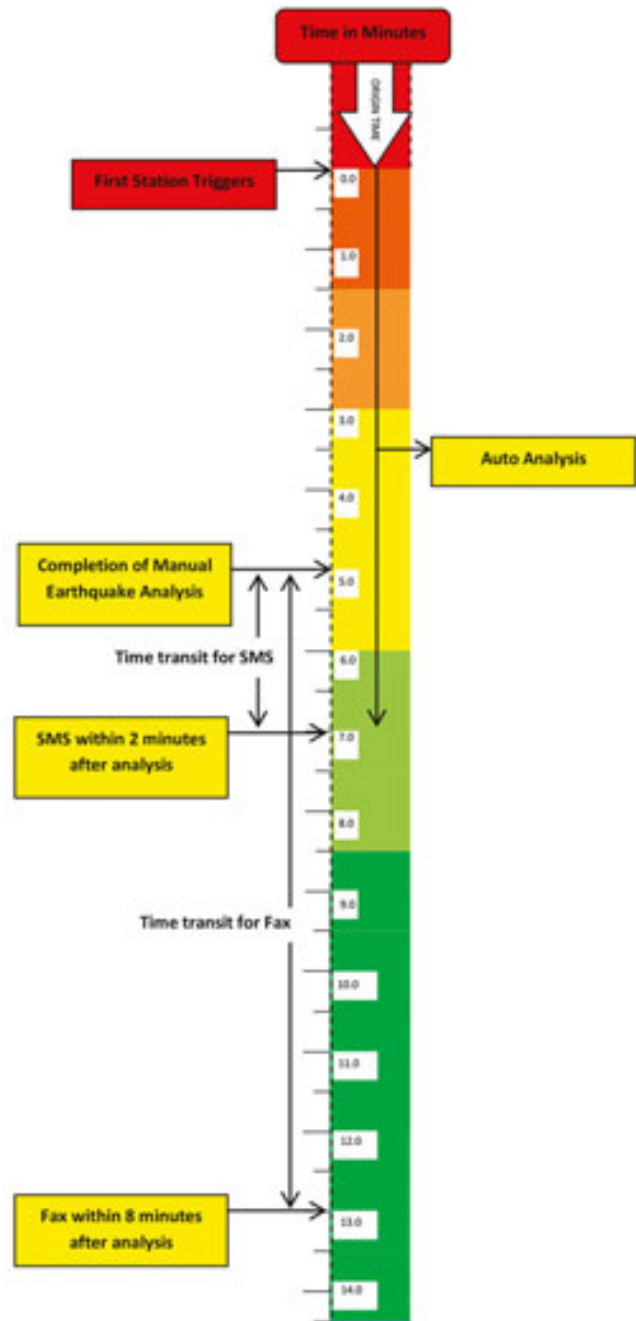


Figure 5. Tsunami warning SoPs, Source; Report developed by NS&TEWC, PMD, 2010.

Through this arrangement, the system installed in a community can be directly activated from PMD Karachi office, using a satellite link. Technically, the warning information received to PMD (about a possible tsunami) will be sent to INMARSAT ground station through TCP/IP link. The information received to INMARSAT ground station then is sent to INMARSAT satellite pointing to area that activates the mass notification systems at Pasni and Gwadar. The system basic building blocks have been shown in Figure 6.

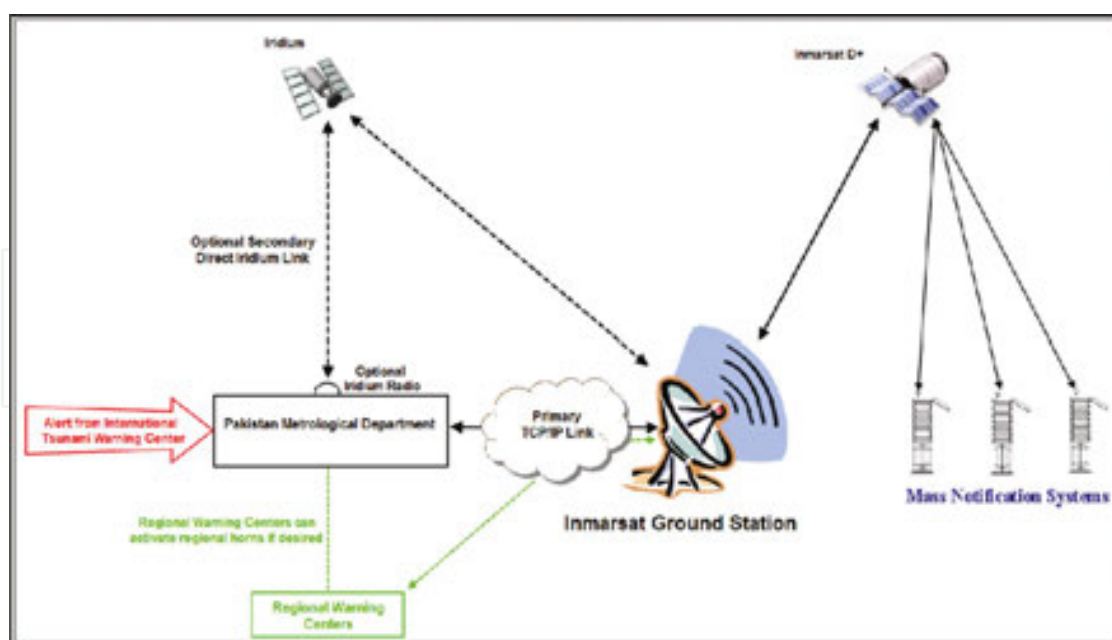


Figure 6. INMARSAT Siren system activated through satellite connection from PMD Tsunami Center Karachi.

3.1.1.3. District disaster management authorities (DDMAs) of the coastal districts

Once DDMAs established (notified) at District Commissioner Office receive an alert from PMD, a warning is issued to the vulnerable communities on the basis of vulnerability assessments. Mode of communication includes high-intensity sirens at mosques and special sirens towers (very limited in numbers). If a power failure occurs, the siren is sounded by police, ambulances, and fire brigade vehicles. The DDMAs maintain communication with these agencies via wireless channels, telephone, fax, GSM in the districts depending upon the availability of the mode of communication. All DCO offices in Sindh also have the facility of video conference, but it again is dependent on the quality of the internet connection. In case of declared emergency the concerned DDMA/DCO office establishes “Emergency Room” on 24-h operational basis to receive and pass on the required information locally and among provincial- and federal-level stakeholders. Local electronic media can also be approached by these authorities for releasing public messages.

However, DDMAs lack appropriate means of reaching to the last mile in case of difficult access coastal area for example boats, helicopters, etc., considering less than half an hour time available before tsunami can attack after a local earthquake hits the area.

3.1.1.4. National and provincial disaster management authorities (NDMA, PDMAs)

NDMA and PDMAs also have SOPs to further disseminate information to a limited number of recipients including media. The NDMA and PDMAs are responsible for communicating the alerts to national and provincial response organizations via press release, emails, phone, faxes, and GSM networks (available list of contacts) and through involving electronic media.

However, it must be noted that because media is more interested in “big news” than in disseminating an early warning, which results in panic. The media, therefore, lacks understanding and training on handling such information in a more appropriate manner.

3.2. Emergency responders

3.2.1. District government

The district government acts as an emergency responder despite having limited resources to mobilize like vehicles, phones, and faxes that are used to relay information. For remote areas that lack phone and fax services, representatives are sent via vehicles and boats to convey the early warning. District government declares the situation as an “emergency” for provincial and federal help if the response is beyond the available resources in the districts. However, assessment of the situation and declaration of emergency takes time; at least 24 h. This can be acceptable in case of a cyclone warning (if received 2 or 3 days earlier); however, for local tsunami, the lead time can be less than 30 min for some coastal areas, which is not manageable by any of the six coastal district administrations.

3.2.2. Police and security agencies (army, navy, coast guards, marine security agency)

Although equipped for immediate relief and emergency response, the armed forces and security agencies do not have an SOP for the dissemination of early warning. However, they do have the means (satellite phones, HF/VHF, etc.) to ensure effective communication to those most at risk. There are some areas in the creek where the access is limited with boats and no direct HF/VHF system setup is available in such settlement. Again the cyclone warning and required evacuation can be managed; however, for local tsunami, it seems difficult to inform the people timely and manage evacuation unless there is a direct mass notification system installed at each such vulnerable community.

There is need to map presence of all these agencies near remote agencies and to develop SOPs that define roles and responsibilities among agencies based on their existing resources.

3.2.3. Nongovernment organizations

NGOs with local presence such as Plan International Pakistan, HANDS Pakistan, International Red Cross (IRC), and many others, collaborate with international NGO coordination groups such as United Nations Office for the Coordination of Humanitarian Affairs and government during disasters until the first phase of recovery. Previous disaster risk management (DRM) and contingency plans (developed for few districts) from 2008 to 2013 show allocation of functions for different line-departments and areas of coordination with NGOs and INGOs [6].

Local NGOs have developed a great network and deep roots in coastal areas of Sindh and Balochistan. These NGOs have all the required local knowledge and access to remote areas; however, such organizations are based on donors funding that usually comes in post disaster situation. Potential of these local organizations can be utilized through mapping and devising SOPs for early warning dissemination to the coastal communities at risk.

3.3. Pilot coastal communities (field survey)

Tsunamis of nearby origin, which account for most tsunami fatalities worldwide pose the greatest tsunami hazard on Arabian Sea shores. The nearby source is the Makran subduction zone (MSZ), an active boundary between converging tectonic plates that descends northward beneath Iran and Pakistan. Earth scientists have recently proposed that the zone can produce an earthquake of magnitude 9. This worst case scales up the 1945 Makran earthquake, which was followed by a tsunami that took hundreds of lives [7]. Coastal Pakistan is also subject to tropical cyclones, as seen recently with cyclones Gonu and Phet.

Today coastal communities of Pakistan are much more vulnerable (to tsunami, cyclone and sea level rise) than they were in 1945 because of high population density, rapid urbanization, lack of land use planning and loss of natural safeguards such as mangroves and sand dunes. In urban areas where the multilayer communication networks exist, it is assumed that emergency information can be delivered quickly, though how to manage evacuation from low-lying parts of Karachi has yet to be determined. Pakistan's coastal villages are vulnerable to marine hazards not just because of meager communications, but also because of poverty and

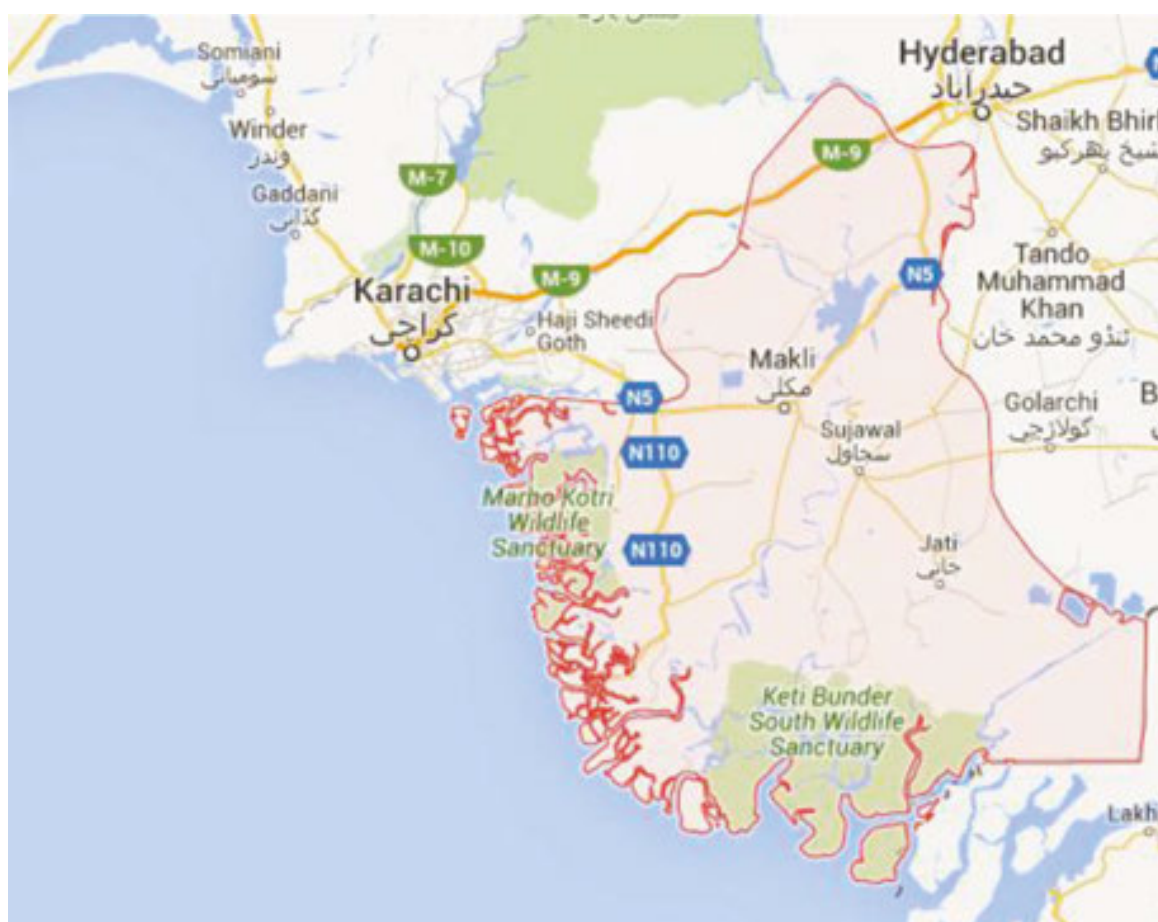


Figure 7. Boundaries of District Thatta, red outlined.

low literacy rates resulting communities' inappropriate level of understanding and responding warnings.

Ten such villages were selected for study of the capacity to receive tsunami warnings. Eight are located in Sindh Province—in Thatta, Sujawal, and Badin districts, mostly located in the Indus Delta—and the other two are in Gwadar District of Balochistan Province. All 10 were visited for field observation of the current situation with regard to the delivery of official tsunami warnings.

3.3.1. District Thatta

Thatta is an ancient city of the Indus delta situated about 100 km from Karachi connected via the national highway. The district Thatta is bounded on the north by district Jamshoro, on the east Tando Muhammad Khan and Badin districts, on the south (Rann of Kutch) and Arabian Sea and on the west by Karachi district. The total area of the district is 17,355 sq. km, whereas the population of the district is around 1.20 million (**Figure 7**).

Communities from the following villages were visited as part of the field survey.

- a. Somar Dablo village (Phirt Creek)
- b. Siddique Dablo village (Tippun Creek)
- c. Dilli Sholani village (Khobar Creek)
- d. Tayyab Jutt village (Bhori Creek)



Figure 8. Research team approaching Bhori Creek, two small adjacent islands can be accessed by boats only.

Almost all surveyed villages have no electricity from national grid and rely on solar panels provided by local NGOs to recharge their cell phones and watch TV occasionally. No land lines phones are available and GSM networks are weak, partial, and occasionally available at certain locations in the surrounding. None of the villages are connected by roads and the only access is through boats that are also used to bring drinking water in canes/tanks and daily groceries for the households from nearby city, that is, Ketī Bandar (**Figure 8**).

These villages lack basic facilities in education and health; the nearest health facilities available are miles away; at Sakra, Gharo, and Ketī Bandar cities. The literacy rate is near zero.

Fishing is the main occupation in this area and women make handicrafts for additional income. Residents of this area lack a local source of clean drinking water and have few sanitation facilities. Freshwater in tankers is purchased at a rate varying from PKR 1000/- to 5000/- (US \$ 10–50) per tanker in different villages except Tayyab Jutt village (Bhori Creek) where wells are dug up for water.



Figure 9. Broken solar panels require maintenance and repairs; the only source of power to recharge torch and mobile phone batteries.

As a result of inadequate sanitation and health facilities, most residents are exposed to diarrhea, fever, and flu. The daily sustenance of residents is on fish and vegetables that are purchased from Keti Bandar town due to unavailability of local grocery shops in the village.

For communication, most households rely on radio signals and cellular phones. However, these villagers are not very fond of listening to the news broadcast by radio. They prefer watching television using solar panels/generator and even this mode is not used for watching televised news on popular channels. Televisions in these households are used as a mode of entertainment to watch movies using solar batteries and generators as power source (Figure 9).

DRR training for emergencies has been provided by WWF-Pakistan to communities of Dilli Sholani village (Khubar Creek). Villagers were glad to receive the training and appreciated the initiatives taken by the local NGOs but mentioned the inconsistency and follow-up of such activities.

Further information of the surveyed villages is given in **Tables 1** and **2**.

Factor/Parameter	Communities	District Thatta, Keti Bunder				District Sajawal		District Badin		District Gwadar, Ormara	
		Phirt Creek	Tippun Creek	Khubar Creek	Bhori Creek	Rohro Creek	Haji Yousuf Goth	Peer Sheikh Prio	Goth Ramzan Sheikh	Sonth Village	Sirki Village
Location	Distance from Tehsil Headquarters (km)	5	5	10	7.5	25	25	25	50	>100	>100
	Distance from District Headquarters (km)	50	60	100	76	70	61	25	50	300	300
	Distance from Coastal Highway (km)	*N/A	*N/A	*N/A	*N/A	*N/A	*N/A	*N/A	*N/A	35	30
	Distance from Coastline (m)	40	20	23	63	22	25	15	500	20	300
Elevation (m) with respect to Sea level		1.8	3.0	8.8	3.0	1.8	6	2.7	8	10	2.4
No. of near available Coast Guard Posts (CGP)		1 (Keti Bunder)	1 (Keti Bunder)	1 (Keti Bunder)	1 (Kharo Chan)	1 (Kharo Chan)	1 (Kharo Chan)	1 (Darya Khan Bridge)	1 (Darya Khan Bridge)	1 (Coastal Highway)	1 (Coastal Highway)
Direction of Location of Coast Guard Post from Community		E	E	NE	E	W	SW	N/A	N/A	N	N
Community Distance from Coast Guard Post (km)		5	5	7.5	10	13.5	9.25	N/A	N/A	40	40
Line of Sight from Coast Guard Post		No	No	No	No	No	No	No	No	Unclear (sandy)	Unclear (sandy)
Terrain Issue from Coast Guard Post		Creek	Creek	Creek	Creek	Located far	Located far	Located far	Creek	Sandy	Sandy
In Case of Tsunami possible Evacuation Route	Exists	Only via boat	Only via boat	Only via boat	Only via boat	Road and Via boat	Road and Via boat	Road	Road and Via boat	Road and Via boat	Road and Via boat
	Towards	**CGP	CGP	CGP	CGP	Inland	Inland	Inland	Inland	Inland	Inland

The pilot communities' structure-related information/data nontrivial to surroundings can be summarized in Table 1.

* Coastal Highway in Sindh Region is not yet completed

** Coast Guard Pakistan Post

Table 1. Communities' structure-related data nontrivial to surroundings.

		District Thatta, Keti Bunder				District Sujawal		District Badin		District Gwadar, Ormara		
Factor/Parameter	Communities		Phirt Creek	Tippun Creek	Khobar Creek	Bhori Creek	Rohro Creek	Haji Yousuf Goth	Peer Sheikh Prio	Goth Ramzan Sheikh	Sonth Village	Sirki Village
Location	Latitude (E)		67°24'29.1"	67°23'85.2"	67°26'19.7"	67°28'71.6"	67°41'80.4"	67°39'13.2"	42°87'06.5"	N/A	25°18'57.899"	25°23'08.999"
	Longitude (N)		24°08'75.2"	24°07'25.0"	24°02'85.6"	24°03'55.8"	24°03'69.2"	24°07'44.4"	26°91'34.7"	N/A	64°13'46.5"	64°06'12.851"
Projected Population			250	300-325	400	2100-2800	50	600	400	8000	600-700	600
Major Population Concentration			Clusters	Clusters	Clusters	Clusters	Clusters	Clusters	Clusters	Clusters	Clusters	Clusters
No. of Households			35	40	50	300-400	350	180	60	800	60-70	60-70
Literacy Rate %			0	0	0 (2 persons are literate)	0	N/A	1% (5 persons are literate)	N/A	N/A	1% (3 persons)	3% (20 persons)
Max. Occupying Area (sq.km)			0.5	1	0.25	0.3	3	2	0.3	3	0.08	002
Community Settlement Pattern			Circular	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular	V-Shaped	Irregular
Available Telecom Networks	Wired	Landline Telephone	No	No	No	No	No	No	No	No	**V-Phone	No
		Internet	No	No	No	No	No	No	No	No	No	No
	Wireless	GSM	Zong, Warid, Ufone (*)	Jazz, Telenor Zong, Warid, Ufone (*)	Zong, Warid, Ufone, Jazz (*)	Zong, Warid, Ufone, Jazz (*)	Warid, Jazz	Jazz, Warid	Zong, Ufone, Telenor (*)	Zong, Ufone, Jazz, Telenor (*)	Zong (*)	Zong (*)
		Coast Guard HF, VHF	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No
		Wireless Internet	Yes	Yes	Yes	Yes	Yes	Yes	No	(*)3G Phone	(*)3G Phone	No
		Satellite Phones	Not Available	Not Available	Not Available	Not Available	Not Available	Not Available	Not Available	Not Available	Not Available	Not Available
		Others	No	No	No	No	No	No	No	No	No	No
		Electricity		No national grid but solar panels	Only solar Panels	No, only torches	No, only torches	Only solar panels	Only solar panels	Only solar panels	Only solar panels	Only solar panels
Radio Network		No	Yes	Yes	Yes	Yes (occasional)	Yes	Yes	Yes	Yes	Yes	
Line of Sight throughout the Village		Clear up to mangroves	Clear	Clear up to mangroves	Clear	Almost clear with vegetation and streams	Almost clear with vegetation and streams	Clear above vegetation	Clear above vegetation	Clear	Sandy	
Terrain		All flat, divided by water	All flat	All flat	All flat, divided by water	All flat	All flat	Almost flat	Almost flat	Almost flat	Sandy	
Background Noise Level			Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural

The pilot communities' individual information be summarized in Table 2.

* partially and occasionally available

Table 2. Communities' structure-related data trivial to surroundings.

3.3.2. District Sujawal

Previously, Sujawal was an old Taluka (Tehsil) of Thatta district, Sindh, Pakistan. In 2013, the Government of Sindh granted Sujawal, the status of a district. It is located at about 20 km west of Thatta on the road from Badin to Karachi. Sujawal is an agricultural area with a few industries. Its residents are diverse in ethnicity and religion.

The following two communities were selected from Sujawal district: (a) Haji Yousuf Goth and (b) Rohro Creek, Misri Jatt Village.

In the surveyed villages, there are no TV sets, radio sets, and 2–3 mobile phone sets per household are available. Early warning signals are usually broadcasted and received on radio sets (two of which were provided by WWF-Pakistan and two by National Rural Support Programme).



Figure 10. Women collecting partly sweat water from the creek for drinking and household purposes at Rohro Creek near Kharochhan city

The primary occupation in the region is fishing. Residents in Yousuf Goth rely on a big pond for drinking water that is filled from the Indus River during the period of June–July and for next 4–5 months whereas in Rohro creek 8 hand pumps have been installed by WWF-Pakistan in 2014 making access to clean water easy for the villagers (**Figure 10**).

Rohro creek has a relatively high literacy rate of 30% of the population, while in Yousuf Goth five persons can read and write among 180 households. Training by WWF-Pakistan led a few families in Rohro Creek to reduce their risk of flooding by elevating their homes.

Detailed information of the surveyed villages is tabulated in **Tables 1** and **2**.

3.3.3. District Badin

Badin district is a part of Lower Indus plain formed by the alluvial deposits of the Indus River. General elevation of the district is about 50 m above sea level that is lowest for the communities lying along the coastline. The southern part of the district is close to the delta of the river Indus

and the land surface is, therefore, relatively low as compared to the northern half. The eastern part of the district is connected with the sand dunes of Tharparkar district. The degree of slope in Badin is negligible; the district is bounded on the north by Hyderabad district, on the east by Mirpur Khas and Tharparkar districts, on the south by Rann of Kutch, which also forms the international boundary with India, and on the west, it is bounded by Thatta and Hyderabad districts (**Figure 11**).



Figure 11. Boundaries of Coastal District Badin outlined in red.

The following two communities were selected from district Badin: (a) Peer Sheikh Krio and (b) Goth Ramzan Sheikh.

Peer Sheikh Krio Bario village is located about 0.5 km from the coast. It is 2 hours travel away main city and the road leading to the city is only half way paved. The village is deprived of any health facility. Twenty of 400 residents are literate and one graduated from University of

Jamshoro. Fishing remains a predominant profession in the village. A large pond that fills up during rainy season is used for drinking water (**Figure 12**).



Figure 12. Access road to Pir Sheikh Kario Bandari Goth, UC Bhugra Memon, Badin.

For early warning signaling, the coast guard post is located on the Darya Khan Bridge couple of miles away. Television sets are available in two of the households and are used to watch Sindhi news on local channels like KTN. Electricity is not available through national grid and solar panels provided by various NGOs are used to recharge cellular phone and torch batteries.

Basic facilities in the Goth Ramzan Sheikh and in nearby area are lacking including education, access to clean drinking water, and communication. There is a government school building in the village that caters to 150 students with a staff of 4. Since the school is relatively new, only school-going children in the area are being educated. The residents get water from canals in the area, which is also used for drinking purposes.

There is not an early warning system in the area. However, there is potential for one. The residents use a TV on a generator and have adequate access to cellular services. Additionally, they use mobile phone to remain updated with current affairs.

3.3.4. District Gwadar

The district Gwadar, with its 600 km long coast line and un-irrigated tracts of Kulanch and Dasht valleys, is located immediately adjacent to the shipping lanes to and from the Persian

Gulf. The 15,216 sq.kms district area is surrounded by Kech and Awaran districts on north and northeast, Awaran and Lasbela districts on east, the Arabian Sea on south and on the west by Iranian territory Sistan.



Figure 13. Access to Sonth Village near Basool River, Tehsil Ormara, District Gwadar.

The following two communities were selected from Tehsil Ormara in district Gwadar: (a) Sirki village and (b) Sonth village. Both villages are far from the coastal highway and can be accessed by four-wheel drive in two hours. Both villages, because they adjoin the shore, can also be reached by seagoing boats. Electricity is not available through national grid, nor are there telephone connections by wire. The GSM network is also very limited and partially available at certain locations (**Figure 13**).

The area has rudimentary communication services. The residents sometimes get access to Zong as a cellular service and also use radio to listen to news. There are no other means of communication available to facilitate an early warning system. Fishing remains a primary source of income in this village. People rely on a water well that is located far from the village for clean drinking water.

Sonth villages have an abundant supply of water from the river. They also often dig wells in the ground, up to 4–6 feet to access freshwater, whereas in Sirki village, for drinking water, villagers usually purchase a 30 liters tank of water at a price of PKR 50 (US\$ 0.5) (**Figure 14**).



Figure 14. View of Sirki Village UC Basool, Tehsil Ormar, District Gwadar.

There is no electricity available in the village, but most households depend on solar panels for lighting and for charging mobile phones' batteries. Zong is the only mobile network whose signals are occasionally available in the region. There are radio sets present in almost every household and people listen to news broadcasted on BBC Urdu and FM Gwadar.

4. Data analysis

With reference to the Section "Pilot Coastal Communities" following information was collected relevant to data on nontrivial, that is, significant and dependent of surroundings of communities studied and data on trivial, that is, insignificant and independent to surroundings. The information is presented in **Tables 1** and **2**.

5. Considerations for effective warning system

The ultimate goal of an effective, warning system is to have the most effective coverage for the most affordable price or cost. Therefore, it is very critical to properly evaluate the structure and local needs of an area before designing and implementing an effective warning system.

The communities’ structural information/data can be scrutinized under following parameters to formulate the basic blocks of possible coastal hazards warning notification system.

5.1. Location and coverage

The information about the location of a community and audiences is very crucial in identifying the type(s) of method and hence the system(s) to be used—for both dissemination and notification of a warning to an area.

The information about population concentration directly links with the location of audience; indoor or outdoor. The type of construction gives an idea about effective penetration of an alert to a particular area. A careful analysis of both parameters can give a better selection of an information dissemination system in terms of effectiveness of an alert.

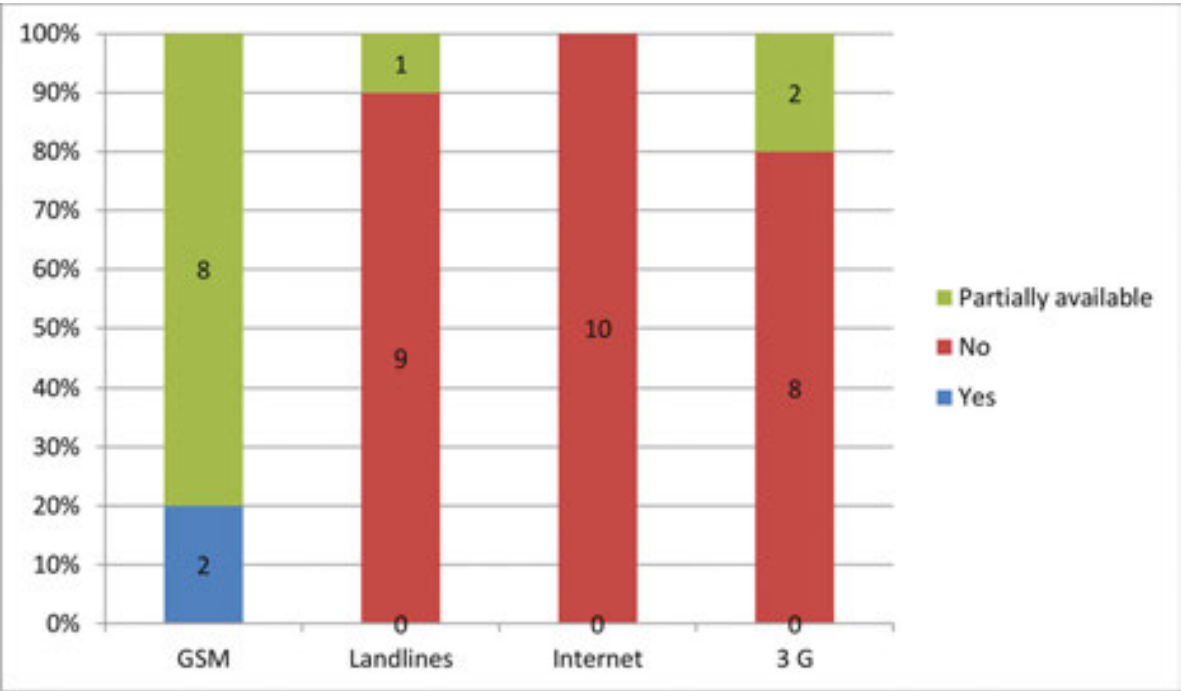


Figure 15. Telecommunication networks availability.

The graph provides an analysis of availability of types of phone coverage in the area. It can be noted that although coverage is partial mostly (80%), but GSM phones were available in all 10 villages as compared to 10 and 20% and respective availability of landline (V phone Pakistan Telecom Wireless phone) and 3 G services in the surveyed villages (Figure 15: Telecommunication Networks Availability). But these mobile networks are partially accessible in most of the villages like weak or no signals in the middle of the island and inhabited area. Villagers have to reach out at certain locations for a certain commercial GSM network. Satellite phones

can be used in all 10 surveyed villages; however, none of the community member is presently using this communication mode because of its very high cost.

5.2. Loudness

The information about total occupying area is also related to determine the loudness of an alert, and hence, the number of effective mass notification units required to a particular area. The loudness of sound from all types of siren is subject to diminishing ten decibels at every doubling of distance between the siren and point of measurement.

Since the occupying area information shows that area of each pilot community lies within 0.1–3 sq.km range, single mass notification unit (for each community) with sound intensity of 120–130 dba can give enough loud sound to cover the whole area for example similar to INMARSAT System currently installed in Gwadar and Pasni cities.

5.3. Area terrain in context with good line of sight

In case of natural hazards like tsunami, loss of lives can be reduced by using an effective timely manner information dissemination and notification method, with least human involvement. This objective can only be achieved if the maximum of hardware used in information dissemination and notification purposes are activated and operated remotely. Generally, radio wireless links located within good line of sight to such systems are used for such purposes. HF/VHF networks presently in use of security agencies are available near most of the villages, that is, six out of ten communities. Few systems where such radio links are not available for information dissemination purposes are activated through satellite links.

5.4. Power source

Almost all mass notification systems rely on electricity; however, mostly, they do not depend on the main power system. Generally, solar panels are used, which have high prices and significantly raise the overall cost of warning notifications system.

As information about pilot communities shows that all villages lack this facility; hence, solar panels (unavailable in Khobar and Bhoori Creek only) can be used to these communities as power source.

Regular electricity network is unavailable in either of the 10 villages, but they use solar energy (very small panels) and battery operated torches.

5.5. Information dissemination from PCG network

Cyclone and tsunami warnings issued by PMD are conveyed to PCG headquarters located at Karachi, which further goes downstream through PCG's internal networks (**Figure 16**).

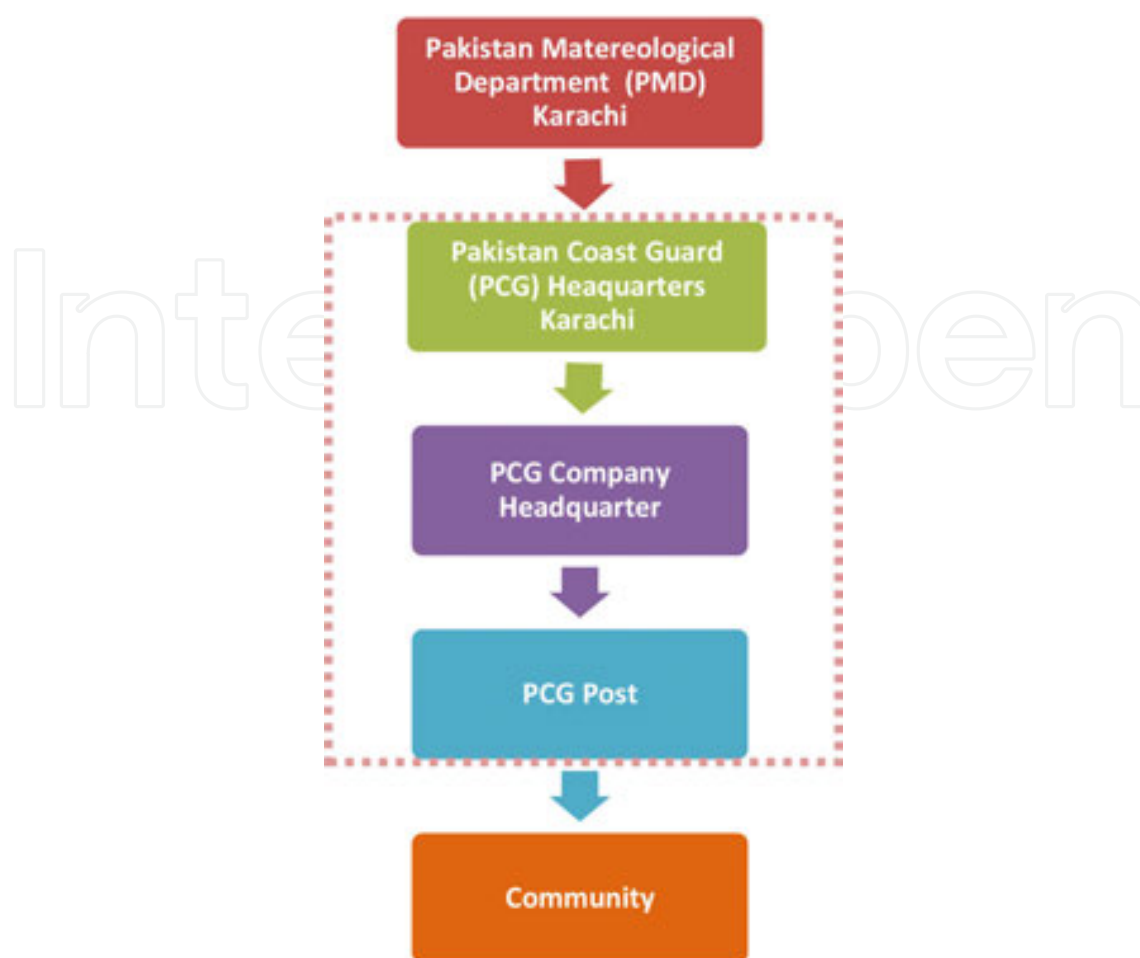


Figure 16. Information flow of coastal hazards early warning from PMD to PCG posts and community.

The cost and reliability of information dissemination from coast guard posts to community is generally affected by following three factors:

1. Distance between post and community
2. Reliability of ways/means of information dissemination
3. Terrain Issues

5.5.1. Personal notification system using PCG posts' human and technical resources

Personal notification uses emergency personnel or trained volunteers to go door-to-door or to groups of people to deliver a personal warning message. As per the field survey:

1. 7 out of 10 communities lie at least 5 km away from nearest PCG post,
2. no other information dissemination means exists in these communities, and
3. evacuation routes are away from communities.

The best use of this system in present situation is its use as enhancement purposes—in combination with any other individual addressable notification system. The merits and demerits of this system are detailed below:

Advantages	Disadvantages
High degree of credibility.	Very time-consuming and slow.
Provides all necessary information and instructions.	Requires recruiting and training large numbers of personnel.
Very strategic notification.	May require a large amount of logistics support (cars, boats, accurate maps and route information, etc.).
Can reach at a specific location.	Unable to reach a very wide area quickly.
Cost-effective if using trained volunteers.	Expensive if using paid personnel.

5.5.2. Communities where information dissemination is not possible through PCG posts

The communities’ data analysis shows that Sirki Village and Sonth Village lie at a faraway distance from the nearest post, with severe terrain and line of sight issues. Hence, information cannot be directly disseminated to these villages through PCGs posts without addition of few repeater stations. Since repeater stations have a considerable cost, it is not feasible to use this method as a solution. In context with present situation, there exist two possible systems in this regard.

5.5.2.1. Mass notification systems linked with satellite activation

Because of its good coverage to the area, mass notification system linked with satellite activation such as NMARSAT system at Gwadar and Pasni instantaneously passes information. The system has (a) high degree of credibility, (b) very effective in terms of time line of an emergency, (c) have average component cost compared to other wireless mass notification systems, (d) running operational coast to satellite link.

5.5.2.2. Addressable notification systems—satellite phones

This type of solution includes satellite phones such as Thuraya. The main disadvantages of such system in present scenario are as follows: (a) continuous operational coast, (b) ownership issues, and (c) satellite phones are generally intended for outdoor usage.

Each of above-mentioned systems has advantages and limitations in its applications to a particular community. If a system has better response and is more reliable at one side (like Wireless operated Mass Notification Systems), then its high cost limits its application.

6. Conclusion

Tsunami generated from a near source has proven its fatality equally for developing and developed nations through 2004 Indian Ocean and March 2011 events in Indonesia and Japan, respectively. The real challenge of relaying the early warning to the vulnerable communities has been the most crucial element, being race against time, allowing mostly less than half an hour reaction period. Every single minute has its significance to be utilized optimistically and well planned.

In case of tsunami generated from Makran Subduction Zone, the PMD, one and the only organization in Pakistan, authorized to issue warnings, uses reliable data obtained from national and global seismographic network to monitor seismic activity that might become the cause of a tsunami. For relaying the warnings, multiple channels of communication are used by PMD including automated GPRS based SMS, mobile phone based SMS, automated fax, manual fax, satellite telephone communication, website updating or email. However, the ground situation at receiving end is quite unable to access such vital information timely through any of the available means of communication which is evident through case studies of 10 coastal communities presented in Sections 3.3 and 4 previously.

The communities studied lies at far distances from respective Tehsil and district headquarters that are the last administrative units of the government to receive any communication with regard to coastal hazard early warnings. **Table 1** shows minimum distance of 5 km to a maximum of 300 km making it extremely difficult for minimum and impossible for average and maximum distant communities to send an “official messenger” for personal notification especially for near filed tsunami threat.

Pakistan Coast Guard posts are established at comparatively closer for example; on average at 16 km apart, in comparison to 35.25 and 822 km average distance of Tehsil and district Headquarters. These posts are also equipped with the fastest means of communication like HF/VHF networks, but presently the communication is restricted to security use only. For bringing this network to disaster, emergency use such as EW, some principal agreements, protocol and SoPs among concerned organizations are to be established.

For other means of communication like phone, TV, and fax and GSM networks, referring to **Table 2**, electricity and landlines are not available in any of the villages studied. However, limited and partial GSM (Global System of Mobile communication) networks are available at some particular locations, which are not yet strong enough to be a reliable mean of EW dissemination. Radio broadcast is mostly available; however, there are two issues yet to be tackled, usually batteries are used as energy source, which are hardly locally available, second is the line of communication between PMD and radio channels is to be streamlined and established.

Population of the communities studied varies from 50 individuals to 8000 concentrated into on average, less than 2 km of area. Four out of ten settlements (located in the creeks) are only accessible through boats; three have population of less than 1000 individuals, whereas only one has maximum population of 2800. In recent past, the only mode of communication used

to convey cyclone early warning to those communities was personal notification, that is, sending local emergency responders; mostly Armed Forces and Security Agency officials on boats and vehicles to inform and support for evacuation to the vulnerable communities. It took hours and in some cases days in comparison to extremely quick actions and reactions required for a local tsunami that might happen like 1945 event.

Therefore, PMD's SoPs alone are not enough to get prepare for a potential threat of local tsunami impacts in Pakistan. The urgent need of developing a well-coordinated time-based SoPs for all stakeholders involved in tsunami warning and evacuation chain is extremely important along with enhancing capacities for technological solutions to quickly relay information to the last mile. This would not be the last but the first step toward mitigation and preparedness as there are still many administrative issues to deal with and to tackle the situation, for example, effective land use managements, expanding data base and information related to the prevailing hazards and vulnerabilities regarding communities and areas under threat of future tsunami. Optimum utilization of available high tech communication networks with armed forces and security agencies, that is, to bring those in the chain of early warning dissemination can reduce burden on limited resources of the nation. Above all, the need of preparing communities to observe natural warning and train them for self-evacuation and emergency response is the most urgent and important line of action at the moment.

7. Recommendations

The following recommendations can help strengthen the early warning dissemination system for coastal hazards in Pakistan.

7.1. Technological solutions

- Considering quick response, better reliability and long life the most preferred system in Phirt Creek, Tippun Creek, Khobar Creek, Bhoru Creek, Misri Jatt Village, Haji Yousuf Goth, and Goth Ramzan Sheikh is a wireless operated mass notification system.
- In case of budgetary constraints, the second preferred solutions to these communities is the use of Radio as warning dissemination and notification system in combination with Personal notification system parallel to this system through capacity building measures taken in target communities.
- For villages in Sirki and Sonth, the best preferred solution is satellite-activated mass notification system. As a second option satellite phones are recommended as mass notification system.

7.2. Land use management

It has been observed that communities tend to settle on remote islands along the coastal belt and due to lack of development in these areas, limited sources of communication exist, which makes communities more vulnerable to coastal hazards. It is recommended that authorities

establish a land use management system that facilitates knowledge on land use along the coastal belt and prevents settlements in remote locations that cannot be easily accessed, especially in times of distress.

It is also important to note that development usually takes place around a central point and infrastructure is installed along that progression. Hence, public and private authorities cannot invest in infrastructure everywhere. This impedes the remotes settlements' access to utilities. However, the government can't be blamed because they facilitate development along a central point and should not be held responsible for providing infrastructure to the most isolated communities.

7.3. Self-response training of communities

Although the communities are aware of coastal hazards, they do not know how to address such a situation if it arises. It is pertinent that the communities are trained on the following:

1. Detection of early warning via natural signs such as abnormal behavior of animals;
2. Basic emergency response, especially how and where to evacuate;
3. Interpretation of bulletins issued by PMD and DDMA's;
4. Different categories of threat and how they should respond to it.

7.4. Communication of early warning in local languages

In addition to the existing format, PMD should ensure that the bulletin formats are available and disseminated in local languages, particularly Sindh and Balochi.

7.5. Training of media

Currently, the media has been observed to sensationalize news instead of reporting it. They should be trained on how to communicate early warning so that panic can be avoided. It would also be in the interest of PMD and NDMA to have designated representatives to coordinate with media in case such a situation arises.

7.6. Research

There is a need for research to investigate the vulnerable areas and analyze the extent of damage based on extrapolation of historically available data. For example, it would be important to highlight the potential increase in Karachi's vulnerability to a tsunami similar to that of 1945, based on the increase in population and infrastructure.

7.7. Delineation of responsibilities

There is need to map the presence of all these agencies and to develop SOPs that define roles and responsibilities among agencies (including security establishments) based on their existing resources for effective dissemination of information.

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