Risk assessment of drowning incidents at Aksa Beach, Mumbai, India.

Dr. Deepali Gadkari\textsuperscript{a} and Subhankar Das\textsuperscript{b}

\textsuperscript{a}Department of Geography, University of Mumbai, Mumbai, India;  
\textsuperscript{b}Department of Geography, University of Mumbai, Mumbai, India

<table>
<thead>
<tr>
<th>The title of the manuscript</th>
<th>Risk assessment of drowning incidents at Aksa Beach, Mumbai, India.</th>
</tr>
</thead>
</table>
| List of authors             | Dr. Deepali Gadkari - First author  
|                             | Mr. Subhankar Das - Second author                                   |
| Corresponding author        | Dr. Deepali Gadkari                                                 |
| and contact details         | Assistant professor  
|                             | Telephone number: 9930629418  
|                             | e-mail address: gadkarideepali@gmail.com                           |
| Second author and contact   | Mr. Subhankar Das                                                   |
| details                     | Research scholar  
|                             | Telephone number: 9153387108  
|                             | e-mail address: subhankardas108@gmail.com                         |
Risk Assessment of Drowning Incidents at Aksa Beach, Mumbai, India.

Abstract
The Aksa beach is one of the most drowning incident-prone beaches in Mumbai. From 2006 through 2018, an average 38 people drowned per year. A total of 445 non-fatal drowning victims have been rescued and 47 died. No research or literature about Aksa Beach's drowning has been published. The incidences are classified on various parameters such as – season, tide time, lunar day, gender and age of the victims, and locations on the beach to assess drowning hazards. The result is that both natural and demographic factors are responsible for drowning incidents. This study assesses the natural and social causes of drowning and suggests a prevention policy.

Keywords: Drowning hazard, tide time, moon phase, risk assessment, prevention policy.

Introduction
Drowning is a serious but not much studied hazard that claims nearly 372000 lives per year worldwide. More than 90% of these deaths occur in low- and middle-income countries. Several thousand drowning incidents have been caused by ocean water globally. These have not been given proper attention by the scientific community. Drowning incidents occur on both the east and the west coast of India. In Andhra Pradesh itself, more than 350 people lost their lives due to rip currents during 2000-2010. Visakhapatnam has reported the highest number of drowning cases, around 293 between 2000 and 2010 year. After Visakhapatnam, the Mumbai coast is second where drowning incidences are considered. The Aksa beach near Malad is one of the most drowning incident prone beaches on the Mumbai coast. From 2006 to 2018, 492 victims faced the drowning hazard at the beach. The number of victims due to drowning has increased significantly on Aksa Beach since 2006. We identified fifteen locations on Aksa beach where 252 incidents happened, 45 died and 447 were rescued. The tidal channel
to the south of the beach and the location opposite the Resort Hotel is the most vulnerable place for drowning. The Aksa beach is straight in shape compared to the adjacent beach. Sandbars and dunes are formed parallel to the beach in the nearshore zone. Some micro geomorphic features exist, such as berm, runnels, and ripple marks, despite the macro geomorphic landform.

The Mumbai Fire Brigade office has appointed lifeguards at the Aksa beach for safety purposes. The lifeguards maintain the record of drowning incidences and send the report to the Fire Brigade Headquarters. In each shift, only three lifeguards are stationed at the beach. In contrast, the beach has more than 200 visitors at peak hours, especially in the afternoon. A CCTV camera has been installed at one location on the beach. However, the live footage of the cameras is not available to the lifeguards who are on the field. The warning signboard is put only at the beach entrance, not all along the beach, where the drowning incidents actually occur. Due to such insufficient measures, drowning incidences frequently occur on and along the beach. So far, hazard and risk assessment for drowning incidences for the Aksa beach has not been carried out.

The Aim

This research aims to understand the nature of drowning hazards in relation to the tide and wave conditions and the hazard preparedness on the beach. The assessment of the Spatio-temporal distribution of drowning incidents and the relationship would be the main thrust of analysis to understand the nature of drowning hazards on Aksa beach.
Figure 1a. Location Map of Aksa beach and locations of drowning incidences, 2006-2018.
Figure 1b. Geomorphic map of Aksa beach of 2018.

Study Area

The Aksa is located along the northern part of India's Mumbai coast. The extent of the study area is between latitude 19°10'38.19" N to 19°12'28.19" N and longitude 72°47'41.88"E to 72°48'21.88"E (Figure 1.a). Aksa Beach is considered the most treacherous in the world ⁴. The Aksa beach has a narrow width of 0.50 km and 1.5km in length. It is relatively straight than adjacent beaches. The beach is sandy and smooth. The sandy backshore is bound by a berm, embryonic sand dunes and marshy land (Figure 1b). Sandbars are found parallel to the beach on the seaward side. Sandbars lead to devolve deep channels between the sand bars and the beach. The southern limit of the beach is marked by a tidal channel and to its south is a rocky shore platform. The Manori creek marks the northern limit.
Data

For this research purpose, both primary and secondary data are used. The primary data are related to beach morphology. Secondary data are on drowning incidents and historical tidal data. Data on drowning incidents are a key factor of the research. The details of the data used are listed in Table 1.

Table 1 - Details of data, type of data, sources of data

<table>
<thead>
<tr>
<th>Data/Variable</th>
<th>Type of data</th>
<th>Parameters/Value</th>
<th>Source</th>
</tr>
</thead>
</table>
| Attribute data Drowning incidents | secondary    | • Number of victims  
• Age  
• Sex  
• Accident time  
• Accident location | Mumbai Fire Brigade office |
| Tide height   | secondary    | Tide height (metre) with date and year               | National Oceanic and Atmospheric Administration (NOAA)(https://tidesandcurrents.noaa.gov/historic_tide_tables.html) |
| Lunar day     | secondary    | Day of moon phase                                   | NOAA(https://tidesandcurrents.noaa.gov/historic_tide_tables.html) |

Methodology

Analysis of drowning data

Since 2006, lifeguards have been appointed at the Aksa beach. Lifeguards maintain a detailed record of drowning incidents on the beach. Those data were collected from the fire brigade's office at Byculla, Mumbai. This study also used data from national news agencies, daily newspapers, national online news websites, and regional/local news websites to collect data on drowning incidents on Aksa beach between January 2006 and December 2018. The drowning data included dates and time, gender, age, and victims' names who died in a drowning incident. So, data was compiled from those sources and carefully cross-checked with record data and
newspaper information. The data were carefully observed, and relevant data were extracted from the whole and filtered for the exceptional type of incidences such as suicide death. The main attributes attached to each incidence include the date, time, exact location of the incidence on the beach, number of victims, age, gender and address of the victims. The geocoordinates of the locations are collected with a GPS survey. A digital database generates by attaching the attribute data to the spatial data. The data is statistically analyzed – classified based on season, lunar days, weekdays, locations, age and gender. Graphs are prepared to represent this analysis. The incidence distribution will further analyze the background of beach morphology and morphodynamics.

**Tide and Lunar Day Data analysis**

The oceanographic information complies with the Aksa beach, which strongly influences the variability locality. The National Ocean Service has published tide data in pdf format oceanwise. The data resolution is on a lunar day basis. The tide data with lunar daywise was downloaded from 2008-2018 from the NOAA website. Tide height and lunar day were extracted as per as drowning date from the whole downloaded data. The Rule of Twelfths \(^5\) is used to determine the exact tide height of each drowning incidence based on the time of the incident. Tide heights (in metres) are reported in ranges from 0.5 to 5.1 metres. The lunar day identifies according to incident days from the Indian calendar. Tide height and Lunar day include in the incidents database and find out the relation between drowning incidents with tidal conditions and lunar day.
Results

**Temporal variations in drowning incidents:**

Results are analyzed based on spatio–temporal drowning incidents and tidal data.

**Figure 2.** Year-by-year trends in drowning incidents and victims (2006-2018)

Figure 2 represents the yearwise distribution of the drowning incidents over 13 years from 2006 to 2018 at Aksa beach. Based on the data collected from the office of the Mumbai fire brigade, it is revealed that the trends of incidents were not consistent, showing an increase in one year and a decline in the next year. 252 drowning incidents had happened over these 13 years. An average of 19 incidents (8% of the total incidents from 2006 to 2018) occurred per year. It may be noted that the maximum number of incidences occurred in 2007 (16% ) and the minimum in 2018 (3%, which is just half of per year's average incidents).
From 2006 to 2018, 45 died and 447 were rescued. There have been an average number of 3 drowning deaths and 34 rescued per year. The highest percentage (18% of total) of drowning deaths occurred in 2007 and the second highest was the year 2009.

**Figure 3.** Distribution of drowning incidents across months (2006-2018)

Figure 3 depicts the month-wise distribution of incidents. Drowning incidents have occurred consistently throughout the years, during all months. During warmer months, the highest number of incidents happened, particularly in the pre-monsoon season. The majority (39%) of incidents occurred from March to May.

**Figure 4.** Number of victims by day of the week (total and percentage of victims, 2006-2018)
In Figure 4, the highest number of people have been drowned on Sundays (25.20%) and the lowest on Thursdays (8.33%) (Figure.4). It is observed that higher drowning incidents (50%) occur on weekends.

**Figure 5.** Time of day and percentage of drowning incidents

The time of drowning incidents has varied throughout the period considered for this study but mostly occurred between 12:00 noon to 6:00 pm (in the afternoon) with 175 incidents (70%), followed by the morning (between 6:00 to 12:00 am) with 52 incidents (21%). Only one incident happened in the early morning from 2006 to 2018 (Figure. 5).
Demographic Variation in Drowning Incidents:

Figure 6. Drowning victims are classified by gender (fatal and non-fatal, 2006-2018)

A drowning that does not result in death is often called a non-fatal drowning and does result in death. It is known as Fatal. Figure 6 shows that males had higher drowning rates than females. Males represented 80% of all drowning victims. Forty-five fatal drownings (died) and 447 non-fatal (rescued) drownings occurred in 13 years from 2006 to 2018. Out of 45 deaths, 38 were male and 7 were female. Of the 447 non-fatal drownings, 363 were male and 84 were female. The maximum number of drowning victims found were from youth (aged 15-30 years old, almost 65% of the total number) for males and females. The highest proportion (40%) of drowning victims is found in the age group of 15-20 years old and medium proportion (25%) of drowning occurred among the young people aged 20-24 years old. The lowest drowning rate (15%) was found among middle adults aged 35-59 years old, seniors old, and kids (5-10 years old). However, kids are remaining victims of drowning incidents. The common factor among child drowning incidents was a lack of adult supervision. In terms of age, older children performed risk-taking activities that may have overestimated their physical skills and performance in relation to physical strength and experience.
Spatial Distribution of Drowning Incidents:

Figure 7 shows the spatial distribution of incidents and drowned victims along the Aksa beach. There were 15 Drowning places where 252 incidents happened between 2006 and 2018; 45 died, and 447 were rescued. The spot opposite Resort Hotel has records of the highest accidents,
including drowned people. In contrast, the opposite Gazebo Bungalow location had the lowest, only once during the last 13 years. The number of incidents and drowned people is 71 and 139 respectively at the opposite Resort Hotel. This spot and the other locations, such as the stream at the southern end of the beach, opposite Aksa village, opposite tower, and Danapani locations, are at the top of the list for drowning incidents (Figure.7). On the other hand, Hamla beach, Marve beach, the spot opposite Harmonium resort, and Mishrawadi bottoms have very rare incidents of drowning.

**Tidal Regime and Drowning Incidents:**

![Diagram showing drowning incidents and drowned victims by tidal water levels](image)

**Figure 8** - Drowning incidents and drowned victims by tidal water levels

Tidal data has been classified into micromareal, mesomareal and macromareal tidal water levels following the method of Masselink & Short. As per the records of the BMC, the date and time of incidents are taken. The time and the height of the high tide on the days of the incidents are identified by NOAA. Based on these two data sets, the height of the tide at the time of incidents is computed. The frequency of drowning incidents in each tidal range is plotted (Figure 8).
Moon Phase and Drowning Incidents:

Figure 9. Coastal drowning by phase of the moon.

Figure 9 draws a pictorial association between incidents and the phase of the moon. It is observed that the frequency of incidents was maximum during the 1-6 lunar days before or after from full moon or new moon. It is nearly 50% of the total. It is observed that drowning frequency increased 2 days before and 3 days after the full moon or a new moon day. While considering only the spring tidal stage, it is more pronounced that the relative rip current drownings were recorded high on either side of spring tide (2 days before and up to 3 days after).

Discussion

The maximum number of incidents (13%) occurred in March over the time considered. Winter is the season with the lowest number of incidents, whereas the pre-monsoon is the highest. There are two reasons for increased drowning incidents during the pre-monsoon season. The first is rough sea conditions (tidal danger, strong current, low pressure, high wind). The second is the increased number of visitors due to the summer break in academic institutions.
During the week, drowned (17%) is more likely to happen on a Monday than a Saturday (15%). This had happened due to increased exposure during holiday long weekends. Drowning victims number describes a positive correlation between the occurrence of drowning incidents and the number of beachgoers, which was low on working days, medium on Wednesday and very high from Saturday to Monday.

The peak hour time of incidents is from 12:00 noon to 6:00 pm. This happens because most beachgoers visit the beach between 12:00 noon to 6:00 pm for their various activities, like swimming, bathing, ball playing and climbing up the rock structure.

Male victims are more vulnerable due to their illogical masculine behaviour than females. Male probably underestimate natural oceanic conditions, like the wave height, tide condition and current pattern. They overestimated their swimming ability. They had tendencies to place themselves in a riskier situation than women. Alcohol drinking is one of the most important causes of incidents for male victims because men drink more alcohol than women near water during bathing time.

In this research, it is also found that the reason behind more proportion of victims in the age group of 15-30 years is that though this age group is mentally and physically supposed to be fit and independent, this age group tends to take more risk than the kids and the old age group.

It is noted that most of the incidents occurred in the mesomareal tidal regime (2-4 meters ht.) at the time of high tide. However, another important observation is that those drowning incidents (drowning and deaths) have occurred even at low tide conditions when the tide range is less than 2 meters.
This suggests that the tidal stage plays a vital role in generating rip current. The mid-low tide time on a day may have the strongest rip currents. The observation is that more people will go into the surf during low-tide times and are more exposed to rip currents. Therefore, it is stated that the tidal stage of the moon phase plays a significant role in occurring incidents.

Nearshore drowning hazards are increasing day to day with increasing beach tourism development. Drowning is one of the neglected hazards for prevention and management. Multisectoral collaboration between government, NGOs, the healthcare sector, researchers, the media, industry, and civil society groups is crucial for drowning prevention at local, regional, and national levels. Multisectoral collaboration means working with other interested parties to achieve a goal. The multisectoral parties may also help each other to achieve their goals. Based on the analysis of data, observations and discussions with the stakeholders at the beach, the authors would like to suggest the following for minimizing the number of drowning incidents.

- **Set up a national plan to keep people from drowning in water**

A national beach safety (or drowning prevention) plan should be drafted consisting of fundamental concepts, objectives, activities, and coordination mechanisms for decreasing and avoiding fatal and non-fatal drowning. It is suggested to include the following in such a plan:

**Signage:**

Signage is also a frequently recommended prevention strategy. Aquatic safety signs are used alert to beach users about the type of hazards, dangerous locations on the beach, submerged dangerous rocky structures, etc. Only a few caution signage flags are placed at the beach entry at Aksa Beach, not the entire beach and the exact spots where accidents occur. So enough warning signage should be put along the beach to attention to beachgoers.
Lifejackets:

A lifejacket plays a significant role in the prevention of coastal drowning. A few lifejackets are kept in the cabin of the lifeguards for their own use and not for visitors. It is recommended that there should be enough lifejackets available for the beachgoers. The lifejackets wearing regulations will be implemented for beachgoers who wish to swim in nearshore water.

Lifeguards and equipment

Only 3 lifeguards are employed in each shift on the Aska beach. Considering the number of visitors and particularly the swimmers, this number of lifeguards is not sufficient. Each shift will require a minimum of six lifeguards with modern rescue equipment on a normal day (approximate number of visitors 200 per hour). Approximately ten lifeguards should be on duty over the weekend, summer vacation, and other holidays, i.e., New year, Christmas day, etc. (approximate number of visitors 300 per hour) to supervise beachgoers.

Camera:

On Aksa beach, only one live camera is installed. However, lifeguards who patrol the beach do not have access to the camera’s live footage. Therefore, the lifeguards should have access to live footage for proper supervision and detect the incidents in real-time to rescue and prevent drowning.

First aid/paramedical facilities:

Sometimes there is a need to hospitalize victims; Lifeguards should be well trained in CPR (Cardiopulmonary resuscitation), which can save the lives of rescued victims. It is a 10-kilometre drive from Aksa Beach to Malad Hospital to hospitalize the casualties. As a result, the rescued victims passed out on the way to the hospital. So there should be an ambulance van, particularly dedicated to the Aksa beach with paramedic facilities near the beach.
• **Strengthen public awareness of drowning through communications**

Public awareness and behaviour change campaigns are crucial if drowning prevention measures are accepted and successful. Public awareness should include knowing the hidden risks factor of the natural condition of the beach environment (like local beach bathymetric, morphology, wave, and rocky platform) awareness. Such maps should be put on the beach. The beachgoers should be allowed to swim between the signage on the beaches patrolled by lifeguards. Indeed, many people are unaware that drowning is a major problem. Therefore, strategic communications should be incorporated into the planning phase of all interventions.

**Conclusions**

The Spatio-temporal distribution of drowning incidents (from 2006-2018) is studied. The relation between the incidents and the factors such as season, tide cycle, lunar day, day of the week, age and gender of victims, and local geomorphic features on the beach is assessed. Among all these factors, local scale morphology is an extremely important factor and other strongly important factors are the tidal cycle, lunar cycle, location within the beach and seasons (month of the year). Young adult aged male people are more vulnerable to drowning incidents. However, Neither the research nor the literature on drowning hazards on Aksa Beach published yet. So, Drowning hazard analysis has significance because this research will include literature at the national level. It is also concluded that more sophisticated & advanced research about management, mitigation of incidents, changes in morphology, and hydrodynamics are required for further study.

**Acknowledgements**

We thank the office of the Mumbai fire brigade for providing a dataset of drowning incidents. We wish to thank many Brihanmumbai Municipal Corporation (BMC) lifeguards. They have
taught me much about real situations on the beach and drowning incidents. We also acknowledge NOAA for an online free service of historical tidal data. We equally thank Mr Nathuram Suryabansi, Ms Anita Jaiswal, and Mr Rupjoyti Changmai for their helpful support during the field survey.

Reference


2. Short, A., Handbook of Beach and Shoreface Morphodynamics, Chichester: John Wiley and Sons.


Table 1 - Details of data, type of data, sources of data

<table>
<thead>
<tr>
<th>Data/ Variable</th>
<th>Type of data</th>
<th>Parameters/Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attribute data</td>
<td>secondary</td>
<td>• Number of victims</td>
<td>Mumbai Fire Brigade office</td>
</tr>
<tr>
<td>Drowning incidents</td>
<td></td>
<td>• Age</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Sex</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Accident time</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Accident location</td>
<td></td>
</tr>
<tr>
<td>Tide height</td>
<td>secondary</td>
<td>Tide height (metre) with date and year.</td>
<td>National Oceanic and Atmospheric Administration</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(NOAA) <a href="https://tidesandcurrents.noaa.gov/historic_tide_tables.html">https://tidesandcurrents.noaa.gov/historic_tide_tables.html</a></td>
</tr>
<tr>
<td>Lunar day</td>
<td>secondary</td>
<td>Day of moon phase</td>
<td>NOAA <a href="https://tidesandcurrents.noaa.gov/historic_tide_tables.html">https://tidesandcurrents.noaa.gov/historic_tide_tables.html</a></td>
</tr>
</tbody>
</table>
List of Figures

Figure 1a. Location Map of Aksa beach and locations of drowning incidences, 2006-2018
Figure 1b. Geomorphic map of Aksa beach of 2018 (b).
Figure 2. Year-by-year trends in drowning incidents and victims (2006-2018)
Figure 3. Distribution of drowning incidents across months (2006-2018)
Figure 4. Number of victims by day of the week (total and percentage of victims, 2006-2018)
Figure 5. Time of day and percentage of drowning incidents
Figure 6. Drowning victims are classified by gender (fatal and non-fatal, 2006-2018)
Figure 7. Percentage of total drowning victims by location

Figure 8. Drowning incidents and drowned victims by tidal water levels
**Figure 9.** Coastal drowning by phase of the moon.
Photo: This image depicts the micromorphology of a beach's sand bar and runnel. The micromorphology is changing rapidly. It has changed within a lunar cycle between the full moon and the new moon. This type of modification is accountable for drownings on Aksa beach.