



Case Report

Study on the postmortem submersion interval and accumulated degree days for a multiple drowning accident



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ABSTRACT

Recreational accidents in aquatic environments leading to death by drowning are quite frequent. Even if they do not usually require forensic investigation, they may provide useful information on the post mortem submersion interval (PMSI) and its relation with accumulated degree days (ADD). This is particularly useful to forensic science since most studies dealing with these matters rely mostly on animal carcasses as human analogues.

In this work we report on a multiple drowning accident resulting in 6 victims. ADD was calculated based on the PMSI and water temperature during this period. PMSI varied between ~7.4 days and ~11.4 days, and estimated body drift from the accident site ranged from 0.5 km to 8.0 km. Surface water temperature in the accident area showed little variation during the PMSI (14.5–16.0 °C). Estimated ADD varied between 115 °C and 174 °C, and between 104 °C and 191 °C when considering the cumulative lower (ADD_{min}) and upper (ADD_{max}) limits for ADD.

We compare the results with recently published data on two similar cases, and suggest a range for ADD that can be assumed as necessary before body floatability is regained after a drowning accident.

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1. Introduction

Death by drowning is a common consequence of recreational accidents in aquatic environments [1–4]. While most of these accidents do not require forensic examination, they may, nevertheless, provide pertinent information to forensic sciences.

The use of human cadavers in studies on the decomposition effects on submerged bodies is rather restrictive for a number of reasons (ethical, religious, environmental, etc.). As such, the use of animals as human analogues is frequent [5–8]. The information acquired in these studies is then used in the analysis and interpretation of the post mortem submersion interval (PMSI) and its relation with accumulated degree days (ADD) in cases involving human bodies. The restrictions on the use of human cadavers highlight the importance of accidental deaths as sources of information, especially in settings where the cause of death, entry point and PMSI are known. These studies of submersion deaths are seen as useful for justice administration and promoting public health [2,9].

The flotation behaviour of a corpse is a particularly relevant aspect to be considered, when analyzing these events [10]. Significant body drift only happens when buoyancy exists [11–14], and there is a relation between the decomposition rate and flotation in cases of drowned victims. Thus, studying ADD can provide relevant clues on the decomposition rate and, ultimately, on the time need for a body to migrate from the bottom, where friction prevents significant drift, to the surface where the body can be transported along significant distances.

In this report we address an accident involving the death of six people taken by a wave while on the beach. The focus of the study is the ADD based on the PMSI and water temperature. We compare the results with recently published data on two similar cases [14], and suggest a range for ADD that can be assumed as necessary before body floatability is regained after a drowning accident.

2. The case and area of study

This report is based on information provided by local Maritime Authorities for the place and time of body recovery. The drowning accident took place at Meco Beach (38°29.36' N; 9°11.03' W), southward from Lisbon, Portugal (Fig. 1), on 15 December 2013 at around 0100 h (Western European Winter Time). Six persons (2 men and 4 women, with ages between 21 and 25 years old) were

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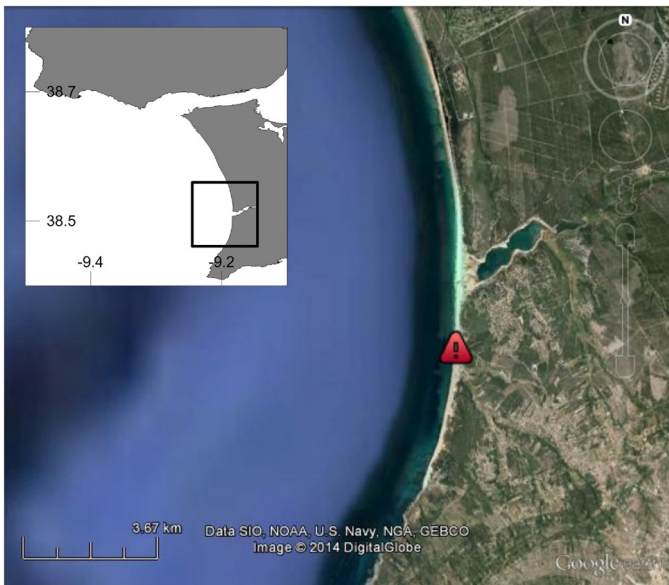


Fig. 1. Aerial image of the Meco Beach area and location of the accident site (point of entry) indicated by the red marker. Inner diagram showing a section of the Portuguese coast where study area is located (black square). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of the article.)

taken over by a wave in unclear circumstances while on the sand, and its backwash pull them to the sea leading to their death. One body was later retrieved at around 0600 h by the search and rescue teams from the Maritime Authorities. The remaining bodies were recovered at different places and time (Fig. 2): one body was retrieved on 22 December 2013 at 1000 h drifting southwest from the accident site; three bodies were found on 23 December 2013, one at 0840 h drifting west from the accident site, two others on the beach at 1320 h and 1430 h, south from the accident site; the

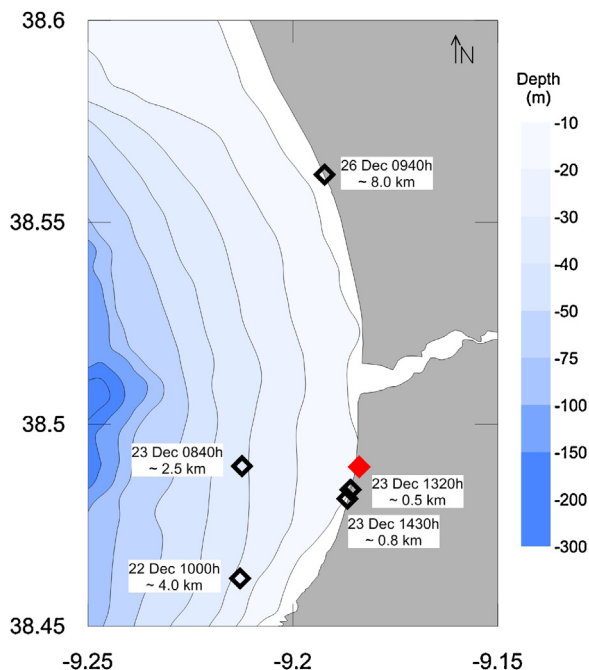


Fig. 2. Zoom of the study area where the point of entry (location of the accident) and body recovery sites are marked with red and black symbols, respectively. Inside panels provide additional details on the time of body recovery and total estimated drift. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of the article.)

last body was found on a beach south from the accident site at 0940 h on 26 December.

Meco Beach is located in the SW Portuguese coast approximately 25 km south from the Tagus estuary. It is mostly composed of sand, but some rocky formation can be seen on the beach and protruding from the water. This site has a very energetic wave regime and local currents are usually along the coast and intense in winter, especially during windy or stormy conditions, such as in the day of the accident, and also on subsequent days. Moreover, strong wave action occurred most of the period (more than 3 m). The area has a semidiurnal and mesotidal regime with amplitudes ranging from 2 to 4 m [15].

3. Methods

The first body recovered having washed ashore a few hours after the accident falls outside the scope of this analysis. Unlike the other cases, the victim died as a consequence of severe spinal trauma (according to media news report) and not of drowning. The other victims are assumed to be drowned, based on the flotation loss of the bodies as a consequence of significant increase in lung weight by water aspiration [16–18], ingestion of water [19–21], or both.

PMSI was calculated for all bodies based on the dates obtained from the Maritime Authorities, assuming that a few hours may differ from resurfacing and body retrieval. Total body drift was calculated as an approximation in Google Earth[®] (Fig. 2), based on the reported sites of retrieval. ADD was calculated based on Sea Surface Temperature (SST) according to Eq. (1), the modified expression [14] of the standard method [13]:

$$ADD = \sum_{i=1}^n \left(T_i \times \frac{h_i}{24} \right) \quad (1)$$

where h_i represents the number of hours in each day (i) during the submersion period (n), and T_i the daily temperature.

Also, as suggested in [14], it was assumed a $\pm 1.5^\circ\text{C}$ variation range on the temperature values used to calculate ADD, thus determining the cumulative lower (ADD_{\min}) and upper (ADD_{\max}) limits for ADD. Water temperature was assumed to be the same as SST provided by satellite imagery from MODIS Aqua, available at the Ocean Color web site (<http://oceancolor.gsfc.nasa.gov>). Data gaps caused by cloud cover in some days were resolved by assuming a linear variation between known values.

4. Results

The calculated PMSI ranged from ~ 7.4 days to ~ 11.4 days, considering the time elapsed between the first and the last body retrieved. The estimated body displacement varied between 0.5 km and 8.0 km, as shown in Fig. 2. Water temperature at the accident site and surrounding coastal area, illustrated in Fig. 3, showed little variation during the PMSI ($14.5\text{--}16.0^\circ\text{C}$), and was within the range expected for this time of year under stormy conditions. Estimated ADD for all cases ranged from 115°C to 174°C , or from 104°C to 191°C if we consider the lower and upper ADD limits. Table 1 condenses the results, and also provides additional information on cumulative lower (ADD_{\min}) and upper (ADD_{\max}) limits for ADD. In addition, the relation of ADD range for all the bodies is shown in Fig. 4.

5. Discussion

5.1. Body resurfacing

Enough putrefactive gases must accumulate for a body to attain sufficient flotation force, undergo vertical displacement and resurface. Since the decomposition rate is a function of temperature [22], and temperature varies significantly in space and time, the necessary time for a body to reach the blotting stage also varies considerably. For this reason the PMSI is not a good indicator to compare with other cases, but instead the ADD [23,24], which resumes the accumulation of thermal units over time. The PMSI observed in this accident varies between ~ 7.4 days and ~ 11.4 days, but with three corpses retrieved on day 8 after the accident. A

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