# MARITIME SECURITY: APPLICATIONS AND PERSPECTIVES TO COMBAT CHEMICAL, RADIOLOGICAL AND EXPLOSIVE THREATS

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## ABSTRACT

*In a globalised world, the potential for crisis in the exchange of goods through sea routes continues to increase due to its low costs and technological progress. The worldwide terrorist threat has increasingly identified transports as a main target, showing several gaps in the field of security to which international conventions and organisations have tried to find solutions. The development of regulations that has followed the awareness of risks in the maritime sector has determined the creation of a complex organisation attending to prevention procedures and emergency measures. The control of maritime security is based on risk analysis and deterrence measures. This modus operandi, which involves public and private actors with different skills, has allowed the achievement of important results. In this work, we analyse maritime security by discussing the method used for risk assessment of passenger and cargo ships in relation to chemical, radiological and explosive threats, and available technologies that can be used to avoid illicit acts on board ships.*

**Keywords:** *Maritime security; chemical, radiological and explosive threats; risk assessment; mitigation actions; substance riskiness.*

## 1. INTRODUCTION

Maritime trade has always held a strategic importance for both the economic development of a state and necessary inner supplies. However, transport and navigation activities are characterised by risks and dangers deriving from the nature of shiploads as well as surroundings (King, 2005; Frittelli, 2008; McNicholas, 2008; Kristiansen, 2013). The problems of protection of human lives at sea, ship safety and security of navigation have been addressed with the issuing of international regulations (Mukherjee & Brownrigg, 2013) aimed at the application of modern technologies for construction, navigation and ship equipment, in order to make maritime navigation safer from risks for ships, passengers on board and transported cargos (Motte, 1996; Roach, 2004).

The need to safeguard human lives and shiploads from emerging risks, in particular illicit acts such as terrorist attacks and piracy, has become more and more urgent

(Murphy, 2013; Talley, 2013). In the aftermath of the September 11, 2001 terrorist attack, the need to respond concretely to the growing global terrorist threat has led to, including in the maritime sector, the definition of a new concept of security, understood as physical protection from deliberate illicit acts against the ship itself, passengers and goods on board, and port facilities (Metaparti, 2010). Hence, in this field, security has supported safety in order to safeguard from risks deriving from transport and navigation activities in naturally dangerous surroundings.

The tendency of modern terrorism seems to be "*the lowest number of attacks, the largest number of victims*" (Laruffa, 2009). For this reason, a passenger ship with large number of people on board could represent a terrorist target for both numerous victims and the public impact on the responsible organisation, compromising the security of trades with a spin-off for the economy. Moreover, ships that transport dangerous cargos (e.g., liquefied petroleum gas) could be terrorist targets in a direct way or to cause explosions in port facilities or near the coast with inevitable consequences on population and infrastructures.

In order to combat international illicit acts in the maritime sector, many legislative solutions have been issued to create common standards of protection and defence for both ships and port facilities (Mukherjee & Brownrigg, 2013). In particular, the international standards for maritime security have been first prescribed in 2002as a new chapter (Special Measures to Enhance Maritime Security, Chapter XI-2, SOLAS '74) (IMO, 2002a) in the International Convention for Safety of Life at Sea (SOLAS) (IMO, 1974), which was consolidated as a safety treaty. This addition, together with a detailed code of security, the International Ship and Port Security Code (ISPS Code) (IMO, 2002b), identifies a large juridical structure to defend ships and ports from terrorist attacks through a series of preventive measures (Laruffa, 2009). The norms adopted by SOLAS are of two different types: Chapter XI-2 and Part A of the ISPS Code are the norms of coercive nature, while Part B of ISPS code is constituted by a series of recommendations and orientations that are useful for obligatory application norms that are not mandatory, except the points considered obligatory by Regulation (EC) No 725/2004.Additional regulations for maritime security (e.g., CE 725/2004 (EU, 2004) and CE 65/2005 (EU, 2005)) have further improved prevention procedures and response measures.

In this work, maritime security is analysed, focusing on chemical, radiological and explosive threats. The method used for risk assessment of passenger and cargo ships in relation to these threats, and available technologies that can be used to avoid illicit acts on board ships, are further discussed.

## 2. RISK ASSESSMENT

As described in the SOLAS and ISPS codes, ships and ports protection is based on the adoption of active and passive measures constructed on three security levels whose application is related to risk assessment (IMO, 2002a, b), and security manoeuvres and devices (e.g., for the ship, the security alert system that communicates the ship's position during piracy attack).The awareness of risk is, undoubtedly, the first step of each assessment. It is important to identify possible threats, their origins and the possible consequences. Essentially, it is necessary to investigate how the item to be protected may be attacked and the occurrence rate. Due to the large number of people on board, a high value of risk for passenger ships has to be assigned; they may be subject to different threats, such as suicide attacks by individuals or groups with explosives, chemical, biological and radiological weapons, and hijacking/hostage-taking, which could lead to the loss of a large number of lives. Nuclear attacks may be practically excluded; although the size of nuclear weapons has decreased considerably such as that they have become transportable (the so-called 'tactical nuclear weapons'), their distribution and availability is extremely limited.

The second step is the attribution of a level of probability, according to the weaknesses of the ship and the interest to attack it, which could depend on what it transports. Values to be attributed range from 1 to 3, depending on whether the probability of that threat occurring is low (1), medium (2) or high (3).

The third step of the risk assessment is the determination of the ship's vulnerability to the attacks, by assessing the security measures and their effectiveness, the technologies used, and the security personnel's training. Specifically, two factors determine the level of vulnerability: a) accessibility to protected structures in attack scenarios, or any physical barriers that deter threat, and b) the security organisation providing security plans, communication skills, surveillance personnel, intrusion detection systems and timeliness in preventing illicit acts. In this case, the range of values is from 1 to 3, depending on whether the vulnerability is low (1), medium (2) or high (3).Thus, in order to reduce risk, it is necessary to decrease the vulnerability, by identifying all the people who come on board, and installing appropriate barriers that allow accessibility to areas that are fundamental for control and navigation of the ship (e.g. main bridge, engine room, steering gear, emergency batteries room, emergency generator room, etc.) to authorised personnel only.

Finally, it is necessary to assess the impact that could result from an attack. The impact is considered limited (1) when the occurrence of the event would result in minimal effects, both from technical and economic points of view, with short recovery time and no considerable spin-off for politics. The impact level is medium (2) when the consequences, although important, are still moderate in comparison with the maximum level of danger. Finally, the impact level is severe (3) when the consequences are particularly important, with considerable social and political implications, both for the loss of human lives and possible interruption of operating conditions, and the restoration costs.

Considering these premises, it is possible to calculate the risk as the product of the values attributed to the threat, vulnerability and impact:

$$R = T * V * I \qquad (1)$$

where $R$ represents the risk, $T$ represents the threat score, $V$ represents the vulnerability score and $I$ represents the impact score. A minimal score (1) will be assigned in the event of a threat that has a low probability of occurrence, a low vulnerability to be attacked, and limited consequences; whereas a maximum score (27) will be given a threat that has high occurrence probability, high vulnerability and serious impact.

After the risk assessment, it is necessary to define which measures are to be taken in order to mitigate the scenario. For the mitigation actions, a score ranging from 0 (minimum) to 14 (maximum) is assigned. In case of a low event probability, it will be enough to adopt ordinary security measures (score of 0-4) to avoid unnecessary alarms or repercussions on the operations on board. When such measures achieve maximum efficiency, the score attributed is 4. Nevertheless, these measures are improvable (score of 5-9), working on the quality of the equipment used, personnel employed and procedures carried out. Finally, to reduce the risk, additional security measures may be adopted, as well as existing ones (score of 10-14).

By including the mitigation actions score into Equation 1, the real risk for a ship is defined as:

$$ER = R - M \qquad (2)$$

where *ER* represents the effective risk, *R* represents the risk as expressed in Equation 1 and *M* represents the mitigation actions score. In the case of maximum risk, even with the most effective mitigations actions, the danger can never be considered completely eliminated. All the steps leading to the final risk assessment can be summarised in the matrix shown in Table 1.

**Table 1: Real risk assessment matrix for passenger and cargo ships.**

| Threat scenario | Possibility of threat ratio * | Vulnera-bility ** | Severity of consequences ratio *** | Level of risk | Mitigation actions **** | Real risk |
|---|---|---|---|---|---|---|
| Individual suicide attacks using explosives | 1 | 1 | 1 | 1 | 0 | 1 |
| | | | 2 | 2 | 0 | 2 |
| | | | 3 | 3 | 0 | 3 |
| | | 2 | 1 | 2 | 1 | 1 |
| | | | 2 | 4 | 2 | 2 |
| | | | 3 | 6 | 3 | 3 |
| | | 3 | 1 | 3 | 2 | 1 |
| Group suicide attacks using explosives | | | 2 | 6 | 3 | 3 |
| | | | 3 | 9 | 4 | 5 |
| | 2 | 1 | 1 | 2 | 5 | 0 |
| | | | 2 | 4 | 5 | 0 |
| | | | 3 | 6 | 5 | 1 |
| | | 2 | 1 | 4 | 6 | 0 |
| | | | 2 | 8 | 7 | 1 |
| Chemical attacks | | | 3 | 12 | 8 | 4 |
| | | 3 | 1 | 6 | 7 | 0 |
| | | | 2 | 12 | 8 | 4 |
| | | | 3 | 18 | 9 | 9 |
| Biological attacks | 3 | 1 | 1 | 3 | 10 | 0 |
| | | | 2 | 6 | 10 | 0 |
| | | | 3 | 9 | 10 | 0 |
| | | 2 | 1 | 6 | 11 | 0 |
| | | | 2 | 12 | 12 | 0 |
| Radiological attacks | | | 3 | 18 | 13 | 5 |
| | | | 1 | 9 | 12 | 0 |
| | | | 2 | 18 | 13 | 5 |
| Hijacking/ hostage taking | | 3 | 3 | 27 | 14 | 13 |

**1, low; 2, medium; 3, high*
***1, low; 2, medium; 3, high*
****1, limited; 2, moderate; 3, severe*
*****0-4, ordinary; 5-9, improved; 10-14, implemented*

## 3. TECHNOLOGIES TO MITIGATE THREATS

In order to increase the security on board ships, the equipment and technologies used for the detection of terrorist threats have to be strengthened and improved. Several techniques are available to identify substances, compounds or explosive mixtures that can be brought on board (Caygill *et al.*, 2012). As the embarkation of passengers and goods on a ship occurs quickly, the technologies employed must provide quick response and low rate of false positives.

A possible strategy for explosives detection is the use of sniffers (explosive trace detectors, ETDs) (Thomas *et al.*, 2007) that utilise a technology based on amplifying fluorescent polymers. Such polymers lose fluorescence when in contact with explosives proportionally to the explosive concentration. The high sensitivity of this tool (in the magnitude of picograms) allows for the detection of explosives present in trace amounts on suspected persons, clothings and items. Furthermore, the ability to detect explosives in the form of vapours makes it feasible to use for inspecting sealed containers. False positives can be easily managed by completing the control process through a detailed inspection of the suspect. The detection results are available within seconds through the reading on a bright display. Moreover, the use of ETD does not require particular technical training for the operator, who can use it with just one hand thanks to the reduced weight and minimum bulk. Considering all these advantages, in order to analyse suspected passengers or baggage, an ETD at each access point of the ship is recommended.

In addition, special equipment for the analysis of liquids is necessary for different access points: these technologies should analyse all the liquids contained in bottles or similar, and provide information related to its potential explosive hazard. A possible solution for this task is represented by Raman spectroscopy, which allows the control of plastic, glass or any other material containers permissive to light passage (Moore & Scharff, 2009). After the identification of a potential risk in a liquid using Raman technologies, it is essential to delegate the analysis to a laboratory for the identification of the substance using different technologies, such as liquid or gas chromatography, coupled with mass spectrometry.

Detection of chemical neurotoxic or vesicant agents can be performed using ion mobility spectrometers (Mäkinen *et al.*, 2010) installed at some crucial points in the ship to analyse airborne dusts. It is completely non-invasive and connectable to an alarm system that sorts the signal on the dashboard instrumentation without the need for a qualified operator. Such devices are mainly common for military applications, in which the risk of chemical attack is more concrete, whereas they are still relatively unknown for passenger and cargo ships.

Ion mobility spectroscopy technology is used by chemical agent monitors (CAMs), an automatic detector of chemical, nerve and vesicant weapons. This tool is optimised in a small and handy portable version. However, the presence of a radiation source inside it makes it very dangerous in case of impact or damage, such as by fire. Additional problems could arise for the modalities of the instrument's safekeeping. Therefore, its adoption on board of a passenger ship cannot be recommended, except in cases of particular and specific information about the possible use of chemical weapons.

Another technology for the detection of dangerous chemical agents is flame spectrometry (Seto *et al.*, 2005), which uses the specific emissions of organic substances containing sulphur and/or phosphorus during a combustion process in an air/hydrogen flame. This equipment does not use radiation sources, and thus, transportation and safekeeping are very simplified.

Finally, to detect radioactive sources, a Geiger-Muller detector can be used (Gallo *et al.*, 2013). Due to its high sensitivity, its utility is not so much to discriminate the type of ionising particle or to obtain information on its energy, but rather to count individual pulses of radiation, even with low ionising power. According to the type of emission, there are Geiger-Muller detectors suitable for α, β or γ particles. A Geiger-Muller detector could be placed inside or immediately after a metal detector portal or an apparatus for security screening of baggages in order to verify the presence of radiation sources at the same time of embarkation. A γ-ray source, diffusible for miles and exclusively dimming with lead plates, could represent a very serious threat aboard a passenger ship, and thus, the use of a Geiger-Muller detector is highly recommended.

## 4. CONCLUSION

In the aftermath of the September 11, 2001 terrorist attack, security measures that were usually taken and appeared suitable to ensure good governance of the seas have been woefully called into question. The need for safety and security of civil society now imposes that public and private entities do their best, with all the resources at their disposal so that the maritime area and the activities that occur in it do not become a place and instrument of terrorist actions. Therefore, a revolution in the scenario of safety and security has occurred. The approach to the concept of security has changed and new strategies, using tools and technologies that are suitable and effective, have been researched.

In the maritime sector, the potential threats that may involve a ship must be continuously assessed and commensurate with the international geopolitical context. In order to continuously improve the counter measures, it is important to estimate the real risk of a naval unit in a certain context. Adequate personnel training and international cooperation programmes are fundamental to effectively prevent and combat terrorist threats. In this manner, operational and technical knowledge in the field of maritime safety can be extended and implemented. Particular attention should be paid to emerging threats, arising from the use of biological, chemical, radiological or explosive (CBRNe) agents. In this context, at the University of Rome Tor Vergata, a team of experts is involved in the training of first responders and decision makers for CBRNe events (Cenciarelli *et al.*, 2013a, b, 2014; Pazienza *et al.*, 2013, 2014; Di Giovanni *et al.*, 2014; Malizia *et al.*, 20110, 2011, 2012; Cacciotti *et al.*, 2014; Sassolini *et al.*, 2014).

A passenger ship represents an attractive target for terrorists, due to the large number of people on board: for this reason, the level of risk is considered high and hence, it is essential to act by increasing security measures, using the latest technology and training staff carefully. To this end, equipment for liquids analysis, radiation sources control, and explosives and chemical weapons detection represent a useful solution to reduce the risk threshold to within the acceptable safety level.

In order to prevent threats in the maritime sector, it is absolutely recommended the installation of specific equipment at each point of access on the ship. Currently, several techniques to quickly identify CBRNe agents, without the need for skilled operators, are available. In particular, ETD allows for explosives detection with high specificity and sensibility. For the analysis of liquids, a possible strategy to be used is Raman spectroscopy, which provides information about the potential riskiness as explosive. Ion mobility and flame spectrometries are useful to detect dangerous chemical agents illicitly brought on board for terrorist purposes. Finally, Geiger-

Muller detectors are suitable to detect radiation sources that are very dangerous for health.
It is important to note that the identification of substance riskiness is not enough; the analysis must continue in a laboratory ashore, using additional technologies for accurate determination of the suspicious substance. The choice of the most suitable equipment to combat all the possible threats that could involve a ship is not easy. Boarding of the ship is the most delicate stage, whereby balancing security with the limited time of embarkation represents the goal to be reached.

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