D5.5 Best practices for the use of drones during environmental maritime emergencies

SUMMARY REPORT

WP 5: Studies for the integrated response to pollution accidents: the use of UAS (Unmanned Aircraft System) in emergency response

Task 5.5: Realization of the technical guide “Best practices for the use of drones during environmental maritime emergencies”

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D5.5 Best practices for the use of drones during environmental maritime emergencies

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This Deliverable will be updated periodically and published only in digital form on the ISPRA and IRA-MAR websites.

Glossary

- ACE Adaptive Cosine Estimator
- BATs Best Available Technologies
- BLOS Beyond Line Of Sight
- BRLOS Beyond Radio Line-of-Sight
- BVLOS Beyond Visual Line of Sight
- EASA European Union Aviation Safety Agency
- EMSA European Maritime Safety Agency
- FAME Fatty Acid Methyl Esters
- FI Fluorescence Index
- GCP Ground Control Points
- GSD Ground Sample Distance
- GPS Global Positioning System
- HALE High Altitude, Long Endurance UAS
- HNS Hazardous and Noxious Substances
- HSE Health and Safety Environment
- HTOL Horizontal Take-Off and Landing
- IR Infra Red
- LALE Low Altitude, Long Endurance UAS
- LAOS Look-Alike Oil Slick
- LIDAR Light Detection and Ranging
- LOS Line of Sight
- LWIR Longwave Infrared Radiation
- NCP National Contingency Plan
- NIR Near InfraRed
- RADAR Radio Detection and Ranging
- RPAS DC Remotely Piloted Aircraft Systems Service Data Center
- RPSA Remotely Piloted Aircraft Systems Service
- SAR Synthetic Aperture Radar
- SCAT Shoreline Monitoring and Assessment Technique
- SEBC Standard European Behaviour Classification
- SLAR Side-Looking Airborne Radar
- SORA Specific Operations Risk Assessment
- STOL Short Take-Off and Landing
- SWIR Short Wave InfraRed
- UAS Unmanned Aerial System
- UAV Unmanned Aerial Vehicle
- VIS VISible
- VTOL Vertical Take-Off and Landing
- WebGIS Web Geographic Information System

Introduction

Note: this report is addressed to all terrestrial and maritime authorities that may be involved in an emergency at sea. In particular, it targets at institutions that have teams, within their organization, specialising in the use of drones in environmental emergencies, such as:

- European Civil Protection Services;
- Maritime Authorities;
- Port Authorities;
- Private entities as oil and gas companies and contractors operating offshore

While the frequency of emblematic maritime incidents in Europe has fallen sharply, maritime transport is undergoing many changes that are altering the associated risk profiles. New concerns are emerging in the face of increasing maritime traffic and larger ships, new cargoes, innovative propulsion systems with new properties, the development of offshore wind farms, and meteorological risks reflecting the consequences of global warming. These changing risk profiles require us to adapt our emergency preparedness, both in terms of capacity and methodology.

In addition, the most recent marine pollution preparedness and response exercises organised at national or regional level (RAMOGEPOL 23) have shown the importance of better coordinating the actions of the various response services, strengthening the land-sea interface in maritime emergency response and identifying new port risks.

The IRA-MAR project "Improving the Integrated Response to Pollution Accidents at Sea and Chemical Risks in Ports" addresses these concerns by seeking to improve the preparedness of Western Mediterranean countries for marine pollution incidents through an integrated approach to response at sea, on the coast and in ports.

Co-funded by the European Civil Protection Mechanism, it aims to:

- increase knowledge of the risks associated with the trafficking of chemical products in ports;
- improve marine pollution detection systems and methods; and
- propose a new holistic and integrated management of emergency response and strengthen the land-sea interface.

Designed to support the beneficiary countries (Spain, France, Italy, Malta, Morocco, Portugal and Tunisia), and benefiting from the international expertise of the project partners (CEDRE, ISPRA and Sea Alarm Foundation), this project presents results that are relevant and useful for all European countries and those of the Mediterranean basin.

It thus contributes to the initiatives and tools facilitating regional cooperation to improve maritime safety and prevent pollution (Bonn Agreement, Ramoge, OSPAR, WestMED initiative) and their respective Action Plans such as the Mediterranean Strategy for the prevention, preparedness and response to marine pollution from ships.

WP 5: the use of UAS (Unmanned Aircraft System) in emergency response

One objective of the project is to test the use of Unmanned Aircraft System (UAS) to improve monitoring, detection and response capabilities to various pollutants. New technologies such as drones have enormous potential to improve the response to maritime emergencies involving the spillage of oil or other chemicals. These new technologies make it possible to improve the effectiveness of the response by more rapidly acquiring the information needed to understand an event and its extent, to have better quality information, and to rapidly define the best response strategies. That's why it's important to understand how they perform in the varied uses and situations presented by maritime emergencies.

An Unmanned Aerial Vehicle (UAV), commonly known as a drone or as a Remotely Piloted Aircraft System (RPAS), is an aerial vehicle without a human pilot onboard. The combination of the platform, its control segment, and its payload is sometimes referred to as the Unmanned Aerial System (UAS). In the text, therefore, when discussing aerial vehicles remotely piloted, it is alternatively reported as drones, RPAS, UAV or UAS.

ISPRA is leading the activities of WP5, which focuses on the studies for the integrated response to pollution accidents, precisely: the use of UAS (Unmanned Aircraft System) in emergency response.

The different sub-tasks of WP5 are:

- Action 5.1: Research on Best Available Technologies (BAT) for shoreline use.
- Action 5.2: Identification of experiences, current good practices and needs of Civil Protection in the use of drones on the shoreline.
- Actions 5.3 and 5.4: Organisation and development of field trials.
- Action 5.5: Production of the technical guide “Best practices for the use of drones to carry out surveys in emergency response”

Actions 5.1, 5.2 and 5.3 resulted in three deliverables:

⇒ Preliminary bibliographic research on the Best Available Technologies for the use of drones in maritime emergency response surveys;

⇒ Analysis and synthesis of the survey “Current equipment, practice, needs and experiences in terms of use of drones in coastal/marine pollution response”.

⇒ Report on field trials and lessons learnt

This deliverable “Best practices for the use of drones to carry out surveys in emergency response”, together to the deliverable 5.4 “Video tutorial on the use of drones in marine environmental emergencies”, summarises suggested best practices for the use of drones during an environmental emergency at sea. It is therefore a description of the main results acquired during the project on the use of drones.

That deliverables are available on the IRA-MAR website (LINK)

This technical guide refer about information and knowledge on the advanced techniques and technologies and the related gaps in the use of drones in marine environmental emergencies due to accidental release of oil or other chemicals. Moreover, the main scenarios in which drones can be used are described and the best setups are suggested to achieve the most effective results.

This Summary Report synthesises the findings of the technical guide “Best practices for the use of drones to carry out surveys in emergency response”, reporting its executive summary

Executive summary

The aim of this technical guide is to gather information and knowledge on the advanced techniques and technologies and the related gaps in the use of drones in marine environmental emergencies due to accidental release of oil or other chemicals.

The activities are part of Work Package 5 "Studies for the integrated response to pollution accidents: the use of UAS (Unmanned Aircraft System) in emergency response" of the IRA-MAR project "Improving the Integrated Response to Pollution Accident at Sea and Chemical Risk in Port". Coordinated by the French General Secretariat for the Sea, the IRA-MAR project aims to help the countries bordering the Western Mediterranean and the Atlantic Ocean (Spain, France, Italy, Malta, Morocco, Portugal and Tunisia) to improve their preparedness and response to pollution risks through an integrated approach to response at sea, on land and in ports. Drones are seen as one of the tools to implement this holistic and integrated approach, facilitating cooperation between scientists, maritime authorities and civil protection services.

Over the last decade in particular, the technological development of drones has progressed exponentially, bringing enormous benefits in a wide range of applications (agriculture, search and rescue after disasters on land, surveillance monitoring of terrestrial areas and military applications). On the other hand, it has been observed that in previous marine environmental emergencies, drones have been used almost exclusively as a kind of "flying" video camera for information purposes to promote the activities of the intervention agencies, or as a means for environmental associations to monitor the actions of the public authorities.

Our research focuses on the use of so-called "small drones", those weighing less than 20 kg, including nano-, micro- and mini-drones. An unmanned aerial vehicle (UAV), commonly known as a drone or remotely piloted aircraft system (RPAS), is an aircraft without a human pilot on board. The combination of the platform, its control segment and its payload is sometimes referred to as an Unmanned Aerial System (UAS). Therefore, when discussing remotely piloted aircraft, the terms drones, RPAS, UAVs or UAS will be used alternatively.

Objectives

Part of the IRA-MAR project is dedicated to examining the potential of using drones in the field of marine emergencies, trying to identify in which areas and how their use should be considered and incorporated into the anti-pollution system put in place by European countries. The aim is to propose the best available strategies and methods for using drones in the fight against accidental spills of hydrocarbons and other noxious hazardous chemicals.

Indeed, the project partners are aware of the enormous potential of the use of drones in the context of marine pollution incidents. Through the use of drones it is possible to:

- facilitate the survey of remote or polluted areas, reducing the risk of exposure to pollutants;
- provide guidance for the production of georeferenced thematic cartography for use by authorities;
- develop synergies and information sharing between maritime authorities and civil protection for the use of UAS in coastal areas;
- notify, inform, and reassure the public about the development of an emergency response, providing photographic and video evidence.

Drones vs manned air vehicles vs satellites

The use of one platform does not exclude the others; each has strengths and weaknesses to be considered. Depending on the circumstances, it is often advisable to use the three platforms in combination. In addition to their advantages in hazardous conditions, UAVs then provide a tool that complements other remote sensing technologies.

In general, drones are cheaper, smaller, lighter, more practical and easier to use than any other Earth observation equipment. They can provide a potential alternative to traditional manned and satellite platforms for the acquisition of high-resolution remote sensing data at lower cost, with greater operational flexibility and versatility.

On the other hand, manned aircraft and satellites can collect data over a larger area and use sensors that cannot be mounted on a drone due to their weight, although the acquisition costs are much higher. In the event of a chemical accident, the use of a drone is preferable to minimise the risk to on field personnel.

Tipologies of drones

Based on the airframe, drones are divided into two types: fixed-wing (aircraft) and rotary-wing (helicopter), usually multi-rotor.

The choice of UAV depends on a number of factors, including the area to be covered, distance from base, flight time, type of sensors carried, terrain, legislation and, finally, the objective of the mission and the type of information required.

Fixed-wing UAVs are more stable and can fly longer at higher speeds, allowing them to cover larger areas in a single mission. For this reason, fixed-wing UAVs are considered the ideal choice for aerial surveys (like for photogrammetry). However, fixed-wing UAVs are not as flexible as rotorcraft and require a runway to facilitate take-off and landing. Some fixed-wing aircraft are now capable of vertical take-off and landing.

Multicopters have lower speeds and shorter ranges, but can carry heavier payloads and remain operational in strong winds, as well as offering better manoeuvrability and the ability to fly at a constant altitude. The most attractive advantage of multi-copters, therefore, is their ability to fly at a constant altitude and also to hover in a single location while pointing at a desired target. Finally, multi-copters have the ability to take off directly from a ship, which opens up the possibility of using them in the open sea. It should be noted, however, that some challenges have to be taken into consideration in launching and landing a drone from a ship, namely:

- limited space to take-off and land the drone;
- difficulty in planning the safety 'return home' function for the boat, which moves during operations;
- interferance with the metal structure of the boat, which could affect the drone's GPS.

Challenges in the use of drones

At the current stage of technological development, there are a number of challenges that can be summarised as follows

- Regulatory constraints. The regulation of the flight of unmanned aircraft is an evolving issue at the international level
- Bad weather restrictions. Strong winds or rain do not allow a drone to fly;
- Short battery life. A small drone can have a maximum autonomy of one hour and is often limited to 30-40 minutes for safety reasons
- Sensor payload limitations. The payload that a small drone can carry is limited to a maximum weight of a few kilograms; some sensors, especially active sensors such as radar or hyperspectral sensors, cannot be mounted;

- Large data management. The data collected in a single flight can be very large and it is important to organise its management, perhaps using a geoportal.

Each drone has to stop surveying activities and land at a home position to recharge. To reduce the time required for recharging, the survey team typically carries several fully charged spare batteries. When the UAS lands at the home position, the survey team swaps the batteries and may connect the discharged battery to a charging port. Once the battery change is complete, the drone resumes its inspection activities

Processing and management data

It should be noted that the density and frequency of data collection is rapidly increasing with the use of UAS for wide area monitoring. It is therefore challenging to manually review and analyse this large amount of data to detect anomalies over a wide area. Therefore, automation of data interpretation using specialised computer software tools supported by artificial intelligence is required to gain maximum benefit from the collected data.

During a single day of operation, a UAS can produce terabytes (TB) of data (high-resolution still images and video). Manual review of this large amount of data is time consuming and may require simultaneous review of different parts of the survey or inspection data, increasing the cost of data interpretation. These limitations can be addressed by deploying Artificial Intelligence (AI) enabled systems to analyse the collected data, and by using cloud-based processing techniques to process the data.

A very important aspect of emergency management is the possibility and necessity for the coordination centre to be aware of the evolving scenario and the complex of activities carried out and information acquired and available.

The use of a “geoportal” goes in this direction, with the added value of unifying all this information with the unique characteristic of the geographic coordinate to which it refers. In this way, each piece of information is allocated in space.

A geoportal (it is essentially a web app) is useful in the management of emergencies, to collect all the data and information that all the specialised components acquire in the field during their operations and are integrated with georeferenced information acquired from other sources (e.g. land registry, municipalities, regions, satellites, etc.).

A specific page could be created in the geoportal for each mission; information acquired by the UAS crews convey on this page and supplemented with information from other reliable sources. The information that reaches the geoportal can be acquired by UAS, but it can also be received by ground teams moving around the territory. In this case, through a very simple and intuitive app, it is possible for the ground teams to photograph, describe and geo-localise a point survey that can be automatically transmitted to the geoportal and shared with the coordination centre.

Each team will have its own identification code and it is therefore also possible to manage the survey carried out. The app also allows off-line captures to be recorded, which are then transferred back to the geoportal when the connection returns

Different scenarios where drones could be employed

Based on the experience gained during the project, it is possible to identify several scenarios in which the use of a drone can improve the effectiveness of an intervention following an environmental emergency at sea.

There is no ideal drone, sensor, software asset for all scenarios. The ideal asset depends on several factors such as:

- location of the area to be surveyed (coastline vs open sea);
- type of contaminant (oil vs HNS);
- period of survey (day vs night);
- size of the area to be surveyed;
- payload of the sensor.

Survey of shoreline

The inspection of coastal areas affected by oil and HNS spills can be implemented quickly with the use of drones. The aim of the inspection is therefore to assess the state of pollution by carrying out what is known as the Shoreline Clean-up Assessment Technique (SCAT).

The survey with drones is developed with a programmed flight to obtain a mosaic of the coastline. The map obtained is processed with specific software to highlight the details observed, such as: the presence of pollutant accumulation points, access routes to the area concerned, the presence of sensitive structures to be considered.

A linear fly is preferable to a zigzag path, as the latter consumes more time and battery, generates more images and increases post-processing time without improving the final data quality. The resulting thematic map can be sent to the command and control room, where decision-makers can take in the information and draw up a clean-up plan.

The use of drones to realise shoreline surveys in remote and hard-to-reach areas is remarkably effective, with significant benefits. This advanced approach based on drone technology has proven to be particularly relevant for a number of reasons:

1. possibility to survey remote and hard-to-reach areas;
2. ability to capture orthophoto images and create mosaics of inspected areas;
3. drones offer significant time efficiencies. Coastal shoreline long hundreds of meters can be inspected in few minutes, anp;
4. assessments could be realised without exposing human personnel to potential risks, eliminating the need to send people into potentially dangerous or hard-to-reach areas.

Creation of three-dimensional cartography (3D maps)

A 3D survey of the polluted coast provides an accurate representation of the coastal environment and information to optimise the planning and execution of pollution assessment and clean-up operations.

The implementation of three-dimensional cartography (3D mapping) can provide a number of significant benefits in the context of coastal and maritime incidents. In particular, 3D mapping can provide several benefits:

- provides accurate topographic detail, capturing every aspect of the terrain
- maps access routes
- provides comprehensive documentation for post-clean up evaluation, facilitating accurate post-intervention assessment

3D reconstruction is also very useful for describing very complex scenarios that unfold in three dimensions. For example, a ship in distress can be visualised in three dimensions to highlight access points or damaged parts that are leaking pollutants into the sea. Another example is the three-dimensional representation of a port area.

Detection and tracking of slicks, drums or containers on the water.

Drones can also detect, track and classify the pollutant. With particular reference to oil or HNS spills, rapid and efficient intervention is required. In particular it is possible:

- detect and classify pollutant slicks;
- carry out their measurement and description;

- track and follow their drift

The multi-rotor drone appears to be the best solution for open sea operations for a number of reasons:

- it can be launched from a ship;
- the flight is essentially manual, which seems to be the best solution in this type of scenario;
- the hovering position is often required to make observations;
- real-time images are important to share with a command centre.

Fixed-wing drones can later be used to expand the search area if a suitable launch and landing site is available nearby.

Particularly functional is the possibility of exchanging all the information with the command centre in real time, enabling the technical staff to assess the evolution of the pollutant at sea and to make quick decisions on the approach and strategy to be adopted for the containment and recovery of the pollutant.

The flight is planned at a sufficient altitude to cover as large an area as possible, while still being able to detect and characterise the pollutant. The altitude will therefore depend on the characteristics of the contaminant. The drone flies over the slick with the aim of describing and measuring the size of the slick and assessing the direction and speed of drift. Orthophotos are taken to assess the extent of the identified patches, their location and, if thickness is known, their volume. If the same measurements are taken at intervals of a few minutes, it is also possible to determine the direction and speed of movement of the slick, its drift.

Thermal imaging in the long-wave infrared can be used to detect oil slicks in the absence of sunlight, then at night. Acquired images, converted to apparent temperature, report target temperature values that may differ from the real temperature due to differences in the emissivity of objects. The apparent temperature detected by a thermal imager is the thermal radiation emitted by a target, which depends on the temperature of the object and its emissivity. Apparent temperature can therefore be used to discriminate between seawater and pollutants, providing the ability to detect pollution slicks even at night.

Moreover, the drone can be flown in 'follow me' mode, where the drone detects a floating object (such as a barrel or container) and 'locks on' to it, following the object in autonomous flight. The camera can detect floating objects up to three hundred metres away. This capability is very important in the event that objects such as barrels and containers are lost from a ship, posing a hazard to navigation and potential marine pollution.

The sensor's ability to track the docked object, even if it is submerged, depends on several factors:

- light intensty
- water transparency
- object size, colour and shape of the object

Guide recovery vessels to the slicks.

Drones can be an excellent tool for optimising and directing containment and recovery operations. By observing the containment and recovery operations in real time, it is possible to check and verify the effectiveness of the anti-pollution means.

It is preferable to use a multi-rotor drone that can be launched from a boat. In the case of an oil spill, the pollution response usually takes place during the day; it may be sufficient to mount a high-resolution video camera as a sensor.

The drone teams need to be in constant contact with the captains of the vessels and the incident commander on the ground to ensure the best possible positioning of the vessels. In particular, it is necessary to provide the captain with a monitor displaying the interface of the management platform, which provides a real-time view of the location of each drone, the images taken by the drones and their operational status. This system allows the images taken by the drones to be viewed in real time in order to better manage any containment and recovery operations.

Monitoring of marine wildlife

Wildlife can be severely affected by marine pollution. Seabird populations come to mind, but other classes of organisms can also suffer: reptiles (sea turtles), marine mammals (cetaceans such as whales and dolphins, pinnipeds such as otters and seals), fishes.

Drones could be used to assess some changes through the following strategies:

- counting the number of individuals in wildlife populations that may have been injured by an oil or HNS spill;
- observe the behaviour of individuals;
- observing signs of contamination in individuals.

Unmanned aerial systems (UAS) have the potential to collect high resolution images of wildlife for life history studies without disturbing the species being studied. The use of a multi-copter is preferable to a fixed-wing drone because it is often necessary to make precise observations (like of individual behaviour) that require stationary flight. If the UAS is operating under a Beyond Line of Sight (BLOS) permit, it could be used to search for wildlife.

Responsible wildlife surveys using drones should be realised by experts experienced in the biology and behaviour of the target animals. Real-time visualisation of the drone's images allows the experts to interact with the pilot during the flight. Close communication between pilots and experts is crucial for an effective and timely response.

The use of a thermal camera makes it possible to observe marine fauna on the surface of the sea or along a cliff, even at night. The temperature contrast makes it possible to distinguish each individual animal very clearly. In the case of coastal colonies of marine fauna, it is advisable to combine 3D photogrammetry with the ability of the thermal camera to observe and detect animals at night.

The use of drones is an important development in the assessment and response of avifauna affected by marine environmental emergencies and in ornithological monitoring studies. It is a powerful method to fill the gap in bird counting at sea. Until now, only rough estimates have been possible.

Sampling of pollutants on water.

A sampler for floating pollutants, such as the Schomaker sampler, can be mounted on a multi-rotor drone to assess its effectiveness and the distance of the instrument from the drone, which is useful to avoid the influence of rotor-induced wind.

The drone is connected to the sampler by a cable of at least 7 metres in length, a sufficient distance so that the wind created by the movement of the rotors does not change the roughness of the sea surface. The flight is essentially in the vertical phase, perpendicular to the surface.

Various devices could be fitted to the drones and offer the possibility to make water sampling, at the surface or at different depths in the sea water surface. If a “small drone” (weighing less than 20 kg) is used, any sampler can be mounted as long as it weighs less than about one kg.

In the context of a real HNS spill, verifying the presence of HNS in the environment, identifying the nature of the pollutant in the case of an unknown chemical, or quantifying whether it is present in the water can provide essential information for decision makers. Realisation of sampling with drones minimize health risks for personnel.

Air quality monitoring

In these scenarios, the main objective is to detect and track the spread of a floating and/or evaporating chemical in order to minimise the risk to those who need to intervene.

Often it is necessary to verify whether the release of chemicals is real or potential; therefore it may be necessary to carefully inspect the hypothetical source (like chemical ship, chemical plant on land, container dispersed at sea, etc.). It is advisable to use multirotor drones to enable stationary observation and inspection of confined spaces (for instance tanks).

Regarding the choice of the most suitable sensors, these could vary from specific thermal cameras to hyperspectral sensors or so-called "laser gas sniffers", which are also useful for volatile substances. In these cases, it is necessary to assess the payload of these instruments, which will clearly determine the type of drone to be used.

Final considerations

Based on the experience gained during the project, some final considerations can be made.

Unmanned aircraft systems can be a valuable tool to implement several operations effectively and quickly in the context of an intervention during a maritime environmental emergency.

Drones can detect, measure and sample a spilled pollutant at sea or in the atmosphere, map and describe a contaminated coastline, and monitor the health and behaviour of marine wildlife. These capabilities help operators to improve their response to accidental pollution, minimising the negative impact on the marine environment and coastal communities.

Use of drones to assess marine pollution requires the combined efforts of a team of experienced drone pilots, experts in assessing the behaviour of oil and HNS spills at sea, and marine biologists. It is essential that these professionals work together, with each individual drone requiring a minimum 'survey team' consisting of:

- A pilot who is fully focused on flying the UAS;
- An expert (navigator) who guides the flight of the UAV to achieve the mission objectives (detection and tracking of pollutants, inspection of remote areas, etc.).

Based on the real-time data, the navigator can ask the pilot to fly and orient the UAS in a specific pose to collect more data from the area of interest.