Abstract

The Sea is often a fragile environment to be protected against possible pollutants. In this context, the present work contributes to its safeguard by proposing a new buoy equipped with advanced sensors for the detection of oil spills. In particular, the buoy is provided with various sensors for the evaluation of both meteorological and marine parameters (e.g. waves, wind, temperature), and chemical/physical data acquired by an electronic nose system specifically designed for the detection of hydrocarbons. The electronic nose is composed of a flow chamber, a chamber equipped with photo ionization sensors, pumps and valves for air inlet and outlet, and a low-cost electronic board. The designed system samples the air above the water and produces data that are processed through two artificial neural networks allowing for a classification of detected hydrocarbons and overall pollution level. Suitable network interfaces and a connector towards a Marine Information System (MIS) allow both for real-time data visualization and for long-term assessment of water quality.

Keywords: Sensorized buoy; Marine pollution; Oil spills; Electronic noses; Hydrocarbons classification

Introduction

The Mediterranean Sea represents a very fragile ecosystem, with the presence of highly polluted areas, heavy commercial and touristic traffic, as well as a particular position and shape, making its waters slowly renewable. In fact, the fast urban settlements expansions, along shorelines, as well as the high and increasing human pressure, made the Mediterranean Sea sensitive to pollutants, especially hydrocarbons, often produced by oil spills and ship transits (Er-Raioui et al., 1999; Ferraro et al., 2009). Therefore, massive global changes could affect this basin more rapidly and intensively than oceans, because of the persistent bio-accumulative chemical compounds that cause problems for the entire ecosystem (Zaghden et al., 2014).

Thus, in the Mediterranean as well as in other areas of Europe and worldwide, a number of safeguard methods has been adopted in last years in order to reduce the negative impact of pollution on the marine ecosystem. In particular, in the northern Tyrrhenian Sea and, specifically, in the area delimited by Corsica, Elba Island, Ligurian coast and Provence, which is considered one of the most important feeding and reproductive places for a number of cetaceans in the Mediterranean, the "*Pelagos Sanctuary*" was constituted. This measure was undertaken in order to preserve such animal species from the disruptive impact of environmental pollution (Azzellino et al., 2012).

Hence, the adoption of innovative strategies for environmental monitoring applied to marine areas has experienced a growing interest in last decades, thus involving state-of-the-art methods to accomplish successfully this aim.

Among the strategies adopted throughout the last years, the employment of electrochemical sensors, sometimes included in systems based on the Electronic Nose (E-Nose) – for air analysis – or Electronic Tongue (E-Tongue) (Czolkos et al., 2016) – for liquid analysis – technology, could represent a useful add-on to current methods, in order to increase their sensitivity and accuracy.

Thus, the aim of this work is to present a system, based on the technologies of E-Nose (Sobanski et al., 2006), integrated into moored buoys (Moroni et al., 2015) and capable of monitoring the presence of hydrocarbons, seen to be the highest-impact pollutants for the marine ecosystem (Clark, 1992), on the sea surface in a given area. This system, which samples the air above the water, could be complemented by similar approaches, for example, integrated into floating vehicles (e.g. AUV, ROV…), as already described in literature (Tonacci et al., 2015, 2016), for a complete monitoring – both from static and dynamic point of view – of an area of interest. The proposed system, based on a sensor-equipped moored buoy, is used as a node in a monitoring network – of different complexity depending on the size and traffic of the area to be monitored – to control areas of interest; to this end, the buoy is equipped with network interfaces allowing for external communication. A connector with a Marine Information System (MIS), offering storage functionalities as well as suitable interfaces for data fruition and processing (see e.g. Cortes et al., 2000; Jordi et al., 2006; Tampucci et al., 2013) is presented. Through the connector, the real-time access to the data acquired by the buoy and transmitted wirelessly to the MIS is possible, together with the request of particular procedures to be performed.

The paper is organized as follows. In Materials and Methods: the basic facts dealing with the buoy and its sensor payload are introduced; the E-Nose from a hardware perspective is presented, the onboard data processing functionalities are described and, finally, communication interfaces and connection to the MIS are reported. Results displays and discusses experimental results while final remarks are presented in the Conclusions section.

Materials and Methods

Sensorized buoy sensors

Two specific issues are on the basis of the proposed approach of using a network of moored buoys for the monitoring: first, the capability of a buoy to carry on sensors and allowing them to work just on the surface of the sea, and secondly due to the geographical location considered for the monitoring. In fact, the “Pelagos sanctuary” is a part of the Mediterranean having many islands and a high density of ships navigating, which make it, at the same time exposed to environmental pollution, and a highly connected sea area in terms of communications coverage.

The proposed moored buoy (shown in Figure 1), is an autonomous system thanks to photovoltaic panels mounted. It is equipped with a configurable sensor payload. Its current equipment consists of: i) a complete weather station, ii) accelerometers for wave motion evaluation, iii) GPS sensor and GSM antenna, iv) batteries and v) the E-Nose which is housed in the immersed part of the buoy and described in detail in the following section.

The weather station is composed of a thermometer for measuring air and water temperature, a hygrometer for measuring humidity, an anemometer and a rain gauge for measuring the wind and liquid precipitation. The sensors are connected to a main electronic board (specifically manufactured for the buoy), which performs the actual measurements. A 3-axis accelerometer fixed to the buoy is also connected to the electronic board and allows for wave motion estimation. Finally, a GPS is also available, providing time information as well as the exact location of the moored buoy. Communications are provided by means of a GSM modem mounted on board and connected to the electronic board; GSM coverage is assured in the area of interest since the buoys are installed not far away from coastlines. However, a satellite modem for communications can be installed without any specific issue or burden to the system.

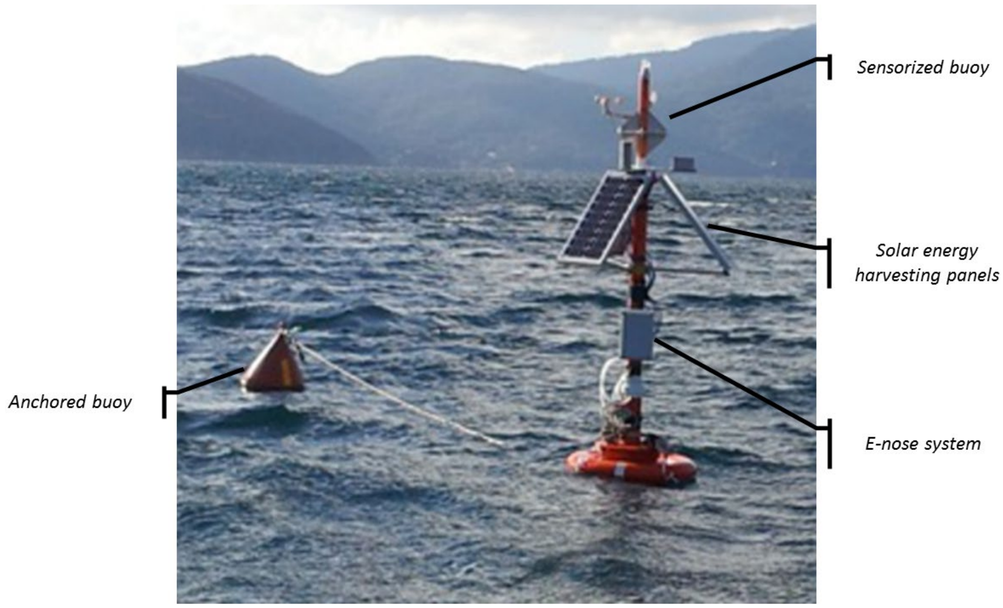

Figure 1 The developed moored buoy at sea, capable of sampling the air above the water through the E-Nose system.

The E-Nose

A very important part of the overall monitoring system presented in this paper is the electronic nose. This important add-on, integrated within the moored buoy, aims to detect, in real time, the presence of pollutants on the sea surface. The E-Nose, a very reliable tool represents, together with other sensor systems included in this platform, an important addition, with respect to the majority of current marine monitoring systems.

The E-Nose-based system is made of several components that ensure its correct functioning and its efficiency. Such elements include two pumps and an electrovalve for airflow inlet and outlet, a flow chamber for air sampling, a sensorized flow chamber and control electronics (composed of a low-cost electronic board, being the system based on the principles of open source and accessibility).

The flow chamber for air sampling was designed and realized in order to have a cylindrical shape, to comply with the sensorized chamber later described. This first chamber features an embedded sensor aiming at checking for the presence of humidity within the chamber, while the two pumps and the electrovalve are interfaced to the electronic board for their activation. In this way, they made possible the correct functioning of the air aspiration/purge system. As already stated, control electronics has been chosen in order to keep its control and programming as simple as possible, as well as to grant its full adaptability to final users' needs, with the employment of open access protocols. Therefore, the low-cost electronic board Arduino Mega 2560 (Arduino Electronic Board, https://www.arduino.cc/en/Main/ArduinoBoardMega2560) was selected, and it demonstrated its effectiveness in the control of the E-Nose system, including pumps and the electrovalve, as well as sensors. The E-Nose control board is physically connected via RS232 to the main electronic board of the buoy.

The sensorized flow chamber is realized in polyether ether ketone (PEEK), a thermoplastic polymer owning a number of important characteristics for this purpose, including the low density (1320 kg/m^3), chemical inertia and good mechanical properties (Young's modulus: 3.6 GPa, tensile strength: 90-100 MPa, 50% elongation at break). This flow chamber, essential to the correct functioning of the E-Nose system, can be equipped with up to six sensors (for the application described here, only three detectors are employed, while other slots are left free for further customization) placed radially in the chamber. The cylindrical shape, as well as the radial symmetry of the sensors, were chosen in order to provide all the detectors with the same amount of airflow. Therefore, the optimal architecture for the chamber could be with two, three or six detectors, respectively placed at 180°, 120° and 60° one from another. In particular, within this work, three Photo-Ionization detectors (piDs, Yin et al., 2013) with different sensitivities to volatile molecules in terms of response amplitude and detection limits are chosen, in order to provide reliable responses even in presence of low concentration of Volatile Organic Compounds (VOCs). Such sensors are classified depending on their label and named as "Silver", "Bronze" and "Black" piD (from the most to the least sensitive one). Among the sensors commercially available, piDs are chosen for the reliability of the data acquired, their stability to experimental condition changes, a nearly absence of drift, as well as their non-responsiveness to major air compounds, such as nitrogen and oxygen (Figure 2).

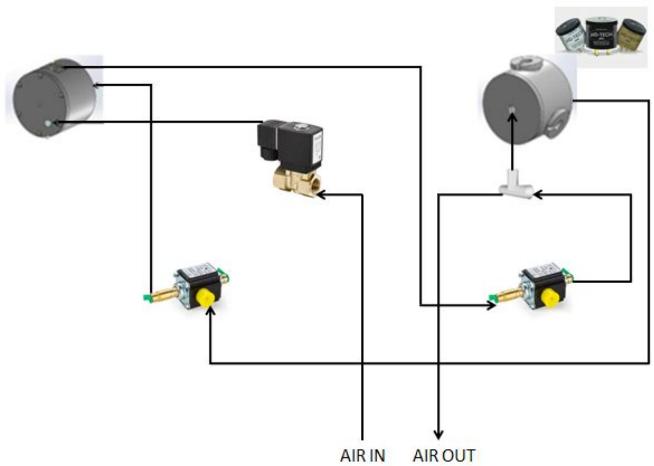

Figure 2 Layout of the electronic nose system.

The functioning principle of the piDs is quite simple: their driving force is the ultra violet (UV) high-energy radiation produced by a gas discharge lamp placed in the upper part of the sensor, within a sensitive window. The lamp radiation has a nominal photon energy of 8.3-11.7 eV, and in our work it produces an energy of 10.6 eV, being represented by a Krypton lamp, characterized by a good VOCs detection range as well as by a long lamp life. Other common lamps are based on Xenon or Argon gases, with an energy, respectively, of 9.6 eV and 11.7 eV. VOCs are exposed to the UV radiation that causes their ionization, in particular referring to those compounds having an ionization potential lower than the lamp energy. This process of ionization converts the molecules into positive ions and negative electrons and their concentration is therefore detected through the use of two electrodes placed in the ionization chamber. Among them, the polarizing electrode is linked to a DC power supply, while the signal electrode is connected to the amplifier input. The electrodes create therefore an electric field, making ions and electrons to migrate toward their electrodes, thus generating a small current, amplified by a specific chip and seen in output as analog or digital signal. The output signal produced is proportional to the difference between the energy of the molecule detected and that of the UV lamp employed, as well as correlated with the concentration of the detected molecule.

As stated above, major air components are not detected by the sensors, due to their higher ionization potential when compared to the piDs lamp radiation energy.

The piDs are power supplied through the E-Nose control board by a 5V supply pin, thus allowing for a low power consumption (current draw being around 30 mA per sensor), not otherwise requiring a pre-acquisition warming time, as occurring in the case of many other kinds of detectors, like Metal Oxide Sensors (MOS).

The principle of operation of the E-Nose solution adopted in this work is as follows: cycles of air suction are defined and performed by activating the inlet duct through pumps and electrovalve movement; the air passed through the air sampling flow chamber where the humidity sensor, also supplied and managed by the electronic board, is placed. Here, the first check of humidity ratio is performed, and the data acquired are important for output post-processing. Specifically, data featuring a too high humidity ratio (typically above 70-75%) could carry on potentially false responses, therefore they have to be discarded or corrected to avoid misleading warnings.

Indeed, high humidity decreases the response in piD sensors by up to 30%, when compared to dry air, because water molecules can absorb UV light without becoming ionized, and thus quench the PID signal, even though they work still better than MOS and other sensors in such conditions. Therefore, a strict control of the surrounding environment is mandatory to achieve reliable results.

Then, the air enters the PEEK flow chamber equipped with the piD sensors that perform an analysis of the VOCs contained in the air sample, providing a corresponding output signal correlated with the total VOCs concentration, as stated above. From the sensorized flow chamber, the air is then purged off the buoy through an outlet pump and electrovalve switch.

Within the purpose here described, the acquisition of data from the piDs is performed at a frequency of

10 Hz, with cycles carried out periodically; each cycle consisted of one minute of air suction, analysis, and purge, followed by a variable and adaptive period of resting, typically set to five minutes, but customizable to fulfill the application requirements. This particular procedure is chosen to assure the acquisition of reliable data, possible thanks to the short resting time needed by the E-Nose to make the sensors clean after each acquisition. Moreover, a lag time between two consecutive acquisitions could allow for a noteworthy energy saving thanks to the lower battery consumption.

The E-Nose system is customizable according to the user's requirements and environmental needs and can accommodate other piDs or other sensors possibly relying on different principles of operation.

E-Nose on-board data processing

The data collected from the piDs are pre-processed directly on the E-Nose control electronics. In order to reduce bandwidth consumption and to improve data transfer rate, a compact representation of the collected data has been chosen to minimize their dimension. In particular, the most significant features, according to the preliminary bench tests and sea trials, are extracted from the raw data consisting of temporal sequences of samples from each piD.

In detail, the following features have been considered:

- Mean value obtained during the acquisition for each of the three piDs (following the order "Bronze", "Silver", "Black" piD) and for the humidity sensor
- Maximum value (peak) obtained during the acquisition for each of the three piDs (following the order "Bronze", "Silver", "Black" piD) and for the humidity sensor
- Peak time obtained during the acquisition for each of the three piDs (following the order "Bronze", "Silver", "Black" piD) and for the humidity sensor, defined as the sample in which each sensor has reached the maximum value

All the processing for this preliminary but fundamental feature extraction is carried out on the E-Nose control board and the results are then transmitted to the buoy main board.

Notice that this pre-processing is extremely useful to reduce the computational load required for system management, therefore allowing an improvement of the performances of the overall system, with considerable energy saving. Without this step, the data collected would have accounted for a significantly higher computational load, with a negative impact on bandwidth consumption either from the E-Nose control board to the buoy main board and in turn to the MIS, with an increase in the system's power consumption.

Artificial Neural Networks

To further process the overall data obtained by the E-Nose and transmitted to the MIS, two artificial neural networks (ANNs), of the type Kohonen Self-Organizing Map (KSOM) have been trained through Matlab R2011b (The Mathworks, Natick, MA, USA). The two ANNs aim, respectively, at: i) assessing the concentration of the compounds detected (Table 1) and, ii) identifying the correct hydrocarbon within the subset of the known stimuli above cited (Table 2).

The characteristics of the ANNs, indicated in Table 1 and Table 2, were chosen to maximize the benefit-cost ratio between the performance of the network and the computational cost required for the operation. To this extent, each of the ANNs was composed of a different number of neurons (12x12 and 15x15), featuring a training on 1500 epochs with 8 and 20 cross validations, respectively. 85% of the data acquired from the laboratory bench test, as well as from sessions at sea held in *La Spezia* and *Capo Enfola* (Italy), was used for the training of the first ANN (80% in case of the second ANN), whereas the remaining 15% (20% in the second network) was employed as test set.

Communication

The buoy is connected with the MIS (see e.g. Tampucci et al., 2013; Moroni et al., 2016 for details about the MIS) which is in charge of receiving, managing and correlating the buoy data and managing the buoy itself.

In more detail, the MIS is able of acquiring, storing and managing heterogeneous data from different sources (Fedra and Winkelbauer, 2002). Aiming at increasing data reliability and at an enhanced understanding of the events occurring in the monitored zones, MIS also cross-correlates the collected data. The E-Nose and the buoy itself are main actors in this context, thanks to their capability of performing reliable in situ measurements.

To create and maintain the connection to the MIS, the buoy is equipped with networking functionalities that are deployed through a specifically designed connector to the MIS. As mentioned before, the communication is bidirectional and is used to send acquired data and to configure buoy functionalities. The configuration of buoy functionalities is focused on the optimization of buoy resource and on ensuring buoy operability (in terms of battery endurance and electronic damage avoidance).

From the hardware perspective, the buoy is equipped with a GSM modem. The installed SIM is enabled to send data packets. In brief, the buoy can be configured remotely by sending text messages (SMS) to the GSM modem, while the buoy can send acquired data to a configurable FTP server in binary format.

From the Buoy to the MIS

The buoy sends to the MIS two kinds of data: i) the actual observations made by the buoy and ii) an auxiliary file containing information and metadata about buoy configuration. The data are placed in a specific FTP folder of the MIS, exploiting a GPRS connection.

Sensors housed in the buoy have different measurement period. Thus, the data to be sent are not usually available together. Aiming at standardizing communication with the MIS and at having only one packet format, each packet contains the observations performed by all the sensors on the buoy. In case a measurement is not available, the packet contains empty data for that sensor. Each packet has fixed length equal to 314 bytes. The basic organization of the packet is shown in Figure 3.

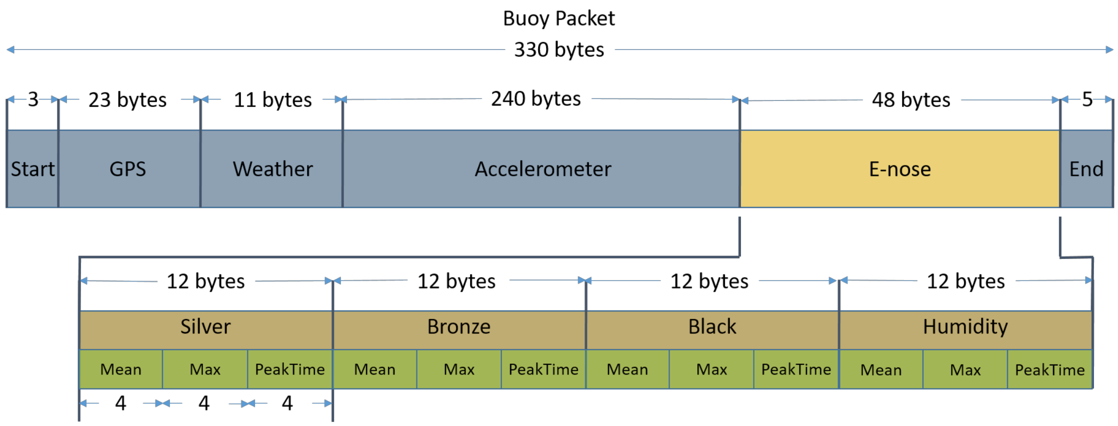

Figure 3 Buoy packet format.

In details:

- The first three bytes and the five ending bytes are used for synchronizing packets and check completeness.
- The following 23 bytes contain data from the GPS, including GPS time and quality of estimate position.
- Weather bytes refer to meteorological measurements, including humidity, temperature, rain, wind speed and direction. Battery status is also included in this block.
- After Weather bytes, the packet of 240 bytes refers to accelerometer data in three directions. These data represent the wave motion.
- E-Nose bytes correspond to E-Nose measurement if performed. Otherwise, they are filled with zeroes. Four sub-packets, each of 12 bytes, compose the E-Nose packet. The sub-packets specify the silver sensor, the bronze sensor, the black sensor and the humidity values. Each sub-packet has three blocks of four bytes that represent mean and max values and the peak time.

In addition, the buoy provides a text file containing information about its configuration, including its ID, GSM network configuration, FTP settings and other parameters for controlling acquisition and transmission frequencies.

Once data are received, the MIS parses and stores them into its inner database. Data are then analyzed in order to recognize the presence of oil spills and to check the correct functioning of the buoy.

From the MIS to the Buoy

The MIS is programmed to detect and manage hazardous situations, as well as to provide an optimal resource management. As mentioned before, once data arrive at the MIS, its proactive functionalities analyze them.

Based on the outcome of this analysis, in case of an alert state, functioning problems or merely for resource management, the MIS can change the buoy behavior.

The MIS communicates with the buoy through text messages (SMS). The buoy is equipped with a GSM modem used both for incoming and outgoing communication. While communication from the buoy to the MIS exploits FTP connection, communication to the buoy is achieved by sending formatted text messages. Indeed, since direct TCP/IP communication is not directly feasible because the buoy has a dynamic IP address, text messages are a convenient way to trigger promptly an update of buoy configuration and behavior.

The MIS is in charge also of controlling the power management of the buoy. Thanks to its internal logic, it defines the optimal acquisition rate in order to ensure the buoy operations. The optimal acquisition rate depends on battery status and on power supply obtained by the buoy solar cells. In case of low battery and/or low power supply (during the night or in cloudy days), the MIS can decide to slow down the acquisition rate; whereas, in case of high battery capacity and/or high power supply it can increase the acquisition rate.

The MIS can change the buoy behavior independently by the battery status and/or power supply depending on the data acquired by the E-Nose. In addition, the MIS can also change the acquisition rate in case of hydrocarbon detection. When a hydrocarbon is detected by the E-Nose, the MIS automatically increases the acquisition rate in order to follow the evolution of the possible oil slick. Finally, after the conclusion of an emergency status, the MIS will automatically slow down the acquisition rate returning it to its normal rate.

E-Nose acquisition rate can be also changed whenever some other MIS sources detect something anomalous. When an anomaly is detected, MIS proactive capabilities can decide to verify and ensure the detection requesting to perform additional measurements to the nearest buoy. If the hydrocarbon detection is confirmed, the MIS will act as mentioned before.

E-Nose data also include the measurement of the humidity in the air chambers. This is a crucial value because it determines the reliability of the E-Nose measure and, in case of high humidity values, is used by the MIS to decide to stop the E-Nose acquisitions. MIS stops the acquisition because high humidity values can indicate a chamber flooding that could result in damage to the E-Nose.

Results

The first step for the characterization of the E-Nose system has been the testing on the laboratory bench, in order to evaluate the responses produced by the piD sensors employed. Such trials have been necessary not only to evaluate the performances of the sensors employed, but also the feasibility of the approach chosen for our specific purpose. To accomplish these aims, the optimal air flow rate for increasing the reliability of the data acquired, thus maximizing the signal to noise ratio (SNR) produced in output by the piDs used, was searched. The result of this characterization revealed an optimal SNR obtained with an air flow rate of 2 l/min, later chosen to properly size the pumps, electrovalves and flow chambers for the system overall. Therefore, the characteristics of the response to the different hydrocarbons were determined using an air flow rate of 2 l/min. Thus, the Minimum Detectable Concentration (MDC) of a set of compounds has been computed, including those hydrocarbons normally present on the sea surface after an oil spill or illicit ship transits through a marine protected area. Such substances on which the system was tested included diesel fuel, gasoline, kerosene and crude oil, of which the MDC parameter has been considered as the minimum concentration capable of producing a SNR of at least 3:1.

The results obtained in this first assessment are consistent with the technical data provided by the piDs manufacturer, thus spanning from a -3 log v/v for the “Silver” piD (most sensitive) to a -2 log v/v for the other two piDs employed. Such results were similar to each other on all the compounds above described (Figure 4).

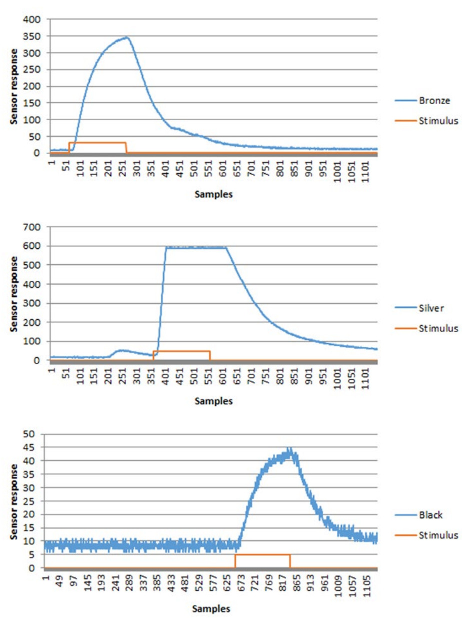

Figure 4 piD Sensor responses to diesel fuel stimuli at a concentration of -2 log v/v.

Another analysis performed in this first test session aimed to evaluate the “T90” parameter, determined as the time needed by a sensor, in presence of odorized air, to reach 90% of the maximum value in terms of output signal amplitude. In this analysis, all the three sensors displayed a fast response time (under

20s between the stimulus onset and the reaching of the 90% of the maximum output signal), in accordance with the characteristics reported in the datasheet provided by the manufacturer. Arising from the data described, the detection time calculated is adequate for early warning the authorities and organizing a prompt response to the pollution accident possibly occurring.

Afterward, the E-Nose system, comprised of its electronics, has been integrated with the overall electronics of the buoy and the communication mechanisms have been tested. In particular, data transfer to the MIS and setting of acquisition frequency have been validated.

Then, two tests for the overall system at sea have been performed. The first of them has been held in *La Spezia*, Italy, located in a highly polluted area, due to ship transits towards the nearby harbor, as well as to sewage from factories located in the suburban area of this maritime town. The second test has been otherwise carried on in *Capo Enfola*, *Elba Island*, within the protected area of the Tuscan Archipelago, thus representing a completely different environment, without the presence of oil spills and ship transits, and with a well-preserved marine environment. The MIS has been able to receive and store all the data, with no appreciable delay. The data acquired during the two sessions have been visualized through the MIS web interface (Figure 5); they have been found as consistent with the two different environmental models typical of the two settings, with pollution detected in the first case and completely absent in the second test.

As stated in the Methods, two ANNs were implemented to classify the stimuli detected by the E-Nose system. The methodology employed provided a good outcome as both the ANNs showed satisfying performances. In particular, the first ANN demonstrated its reliability in classifying stimuli into three risk classes (high, moderate, low risk) in 88.45% of cases, with only an 11.55% of misclassification. On the other hand, the second ANN provided a correct feedback in 80.83% of cases, failing to recognize the correct hydrocarbon in just 19.17% of trials, a noteworthy result considering the similar chemical composition and properties of the hydrocarbons taken into account for characterizing the system.

TABLE 1. ANN FOR HYDROCARBON CONCENTRATION LEVELS ASSESSMENT

ANN size (neurons)	12x12
Training epochs	1500
Number of cross validations	8
Data normalization range (min-max)	0.1-0.9
%Training Set/Test Set	85%/15%
%Correct classification	88.45%
%Misclassification	11.55%

TABLE 2. ANN FOR HYDROCARBON IDENTIFICATION

ANN size (neurons)	15x15
Training epochs	1500
Number of cross validations	20
Data normalization range (min-max)	0.1-0.9
%Training Set/Test Set	80%/20%
%Correct classification	80.83%

%Misclassification	19.17%

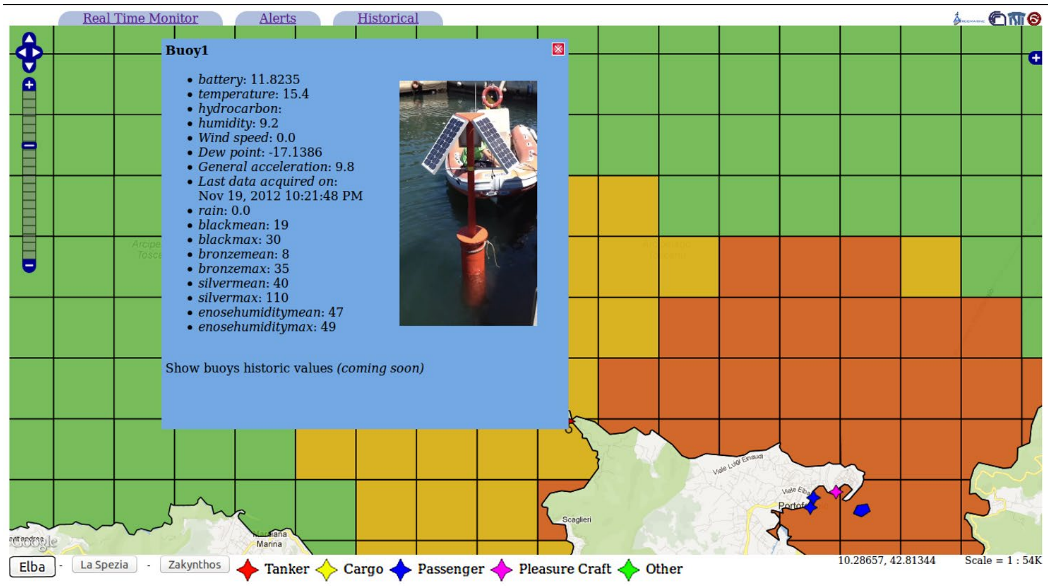

Figure 5 Buoy data including E-Nose visualized through the MIS web interface.

Conclusions

In this paper, we have presented a novel system for the detection of environmental pollution caused by hydrocarbon spills on the sea surface. In particular, an innovative moored buoy integrating an ad-hoc designed E-Nose for pollutant detection has been described. The buoy, whose custom electronics and mechanics have been discussed in the text, was also integrated into a more general framework for sea monitoring thanks to a connector to the Marine Information System (MIS) presented in Tampucci et al. (2013). Thanks to this integration, it is possible to analyze in real-time the data acquired by the buoy and to explore historical data in order to understand seasonal trends. In addition, the data acquisition and transmission frequency can be configured remotely, in order to adapt the buoy behavior to the level of monitoring required at a particular time. The E-Nose itself, even as a standalone solution, is capable of detecting hydrocarbons normally present in illicit discharges and oil spills. It has been shown to provide reliable results in terms of repeatability and reproducibility of the signal acquired under similar conditions, thanks to the good stability of the sensors employed. Moreover, the response in terms of sensitivity (specifically, the minimum detectable quantity) has been largely forecasted before the test session, being characterized by the sensitivity of the different sensors employed and reported in the datasheet provided by the manufacturer. Additional processing methods have been included for discriminating several levels of hydrocarbons concentration and for their discrimination into classes. Such methods, based on a machine learning approach, have shown very promising results, also considering that hydrocarbons employed for this analysis were chemically similar, making their identification challenging.

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Contributors

DM, GP and MT developed the MIS, were in charge for communication part between buoy and MIS, acquired the data, contributed in writing and revision of the manuscript; OS conceived the study, was scientific responsible for the communication and MIS infrastructure and reviewed the manuscript; CD and AT implemented the E-Nose system, conducted the tests,

CONTRIBUTED IN WRITING AND REVISION OF THE MANUSCRIPT. ALL THE AUTHORS ALSO APPROVED THE FINAL VERSION OF THE MANUSCRIPT.

CONFLICTS OF INTEREST: NONE DECLARED.

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