New cost-effective, interoperable sensors tested on existing ocean observing platforms in application of European directives

The COMMON SENSE European project

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Abstract— **The European COMMON SENSE project aims to support the implementation of European Union marine policies such as the Marine Strategy Framework Directive (MSFD). The project has been designed to directly respond to requests for integrated and effective data acquisition systems by developing innovative sensors that will contribute to our understanding of the functioning of marine environments. It aims to develop and provide cost-effective and multi-functional innovative sensors to perform reliable in-situ measurements in the marine environment. The core project research will focus on increasing the availability of standardised data on: eutrophication; concentrations of heavy metals; microplastic fraction within marine litter; underwater noise; and other parameters such as temperature and pressure. This paper will shortly describe the new systems that are developed and the different approaches used during the testing activities**

Keywords— sensors; marine monitoring,; eutrophication; heavy metals; microplastic; underwater noise

I. Introduction

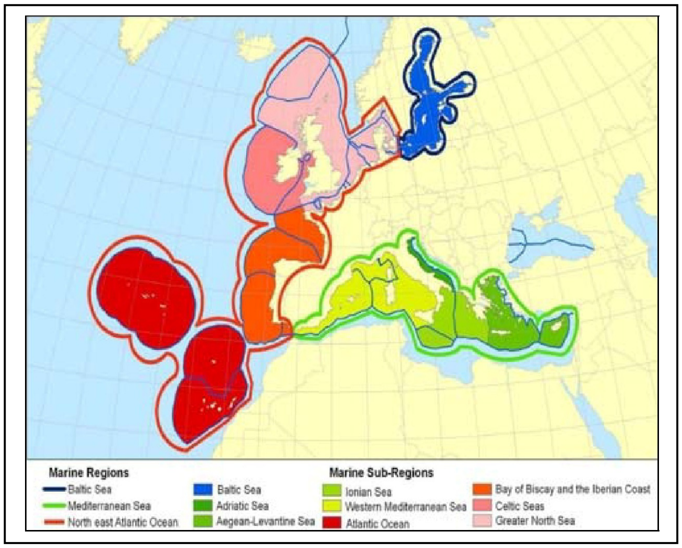
Water is one of our most precious and valuable resources that must be protected, defended and treated as such as defined by the Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000. This has been further underlined, also for the sea and its resources, by the Marine Strategy Framework Directive (MSFD) [1, 2]. A number of organic and inorganic contaminants, such as petroleum hydrocarbons, other persistent organic pollutants, mercury and heavy metals are considered as priority pollutants in water bodies. New and efficient methods are needed for monitoring the implementation of various EU agreements and national programmes on reduction of water contamination, and also for climatological studies. Relatively recent advancements in the field of sensing technologies have brought new trends in the environmental field. The progress in micro-electronics and micro-fabrication technologies has allowed the miniaturization of sensors and devices, opening a series of new and exciting possibilities for pollutants monitoring. Moreover, robotics and advanced ICT-based technology (in particular, the extensive use of remote sensing and telemetry) can dramatically improve the detection and prediction of risk/crisis situations related to water pollution, providing new tools for the global management of water resources.

In order to respond to EU policies and protect/manage through sampling the marine environment, the 40-months EU FP7 project COMMON SENSE[1], which started in November 2013, works in order to define new approaches and strategies to increase the availability of standardized data on eutrophication [3], concentrations of heavy metals [4] (Pb, Hg Cd, Zn and Cu) or contaminants (descriptor 8 of MSFD), microplastic fraction within marine litter [5], and underwater noise [6]. Furthermore, the project also addresses additional new sensors for innovative piro and piezo resistive polymeric temperature and pressure sensors and nanosensors for autonomous pH and pCO2 measurements. This development of innovative sensors for integrated and effective data acquisition systems will contribute to our understanding of how the marine environment works. Innovative sensors are developed and tested on different available platforms like research vessels, nautical platforms, oil platforms, buoys, submerged moorings drifting buoys and smartbuoys. Specific protocols will be followed to verify the quality of the acquired data in different sea conditions (temperature, salinity, depth) and period of maintenance. These protocols are necessary for the definition of deployment procedures, how to avoid/minimize conflicts with daily professional activities (compatibility issues), calendars and availability, sensor operability, optimization, transmission of data specificities, involvement of stakeholders (including cooperation issues) and all other possible information that will be useful.

The realization of innovative sensors also includes the definition of different possible transmission modes.

[1] http://www.commonsenseproject.eu/

Fig. 1. Field testing activities with the avaialble platforms will allow the COMMON SENSE project to partially cover the marine regions and subregions included in the MSFD./



Different sensors mean different data acquisition, storing and transmission systems to be verified like SD internal memories, USB memory or transmitted by telemetry such as GSM, Wifi/Wimax. This means that deployment and recovery methodologies will also be defined accordingly. Acquired raw data will provide information on sensors performances. The data management systems should allow for event detection, event classification (identification of false positives/negatives), and data smoothing (for display purposes). Presently, we are about at mid-term of the project with the realization of sensors and data management system definition trying to provide protocols and calendars for the testing activities starting at the end of the second year. Here we provide a short review of the sensors that will be realized followed by a short description of the novel sensors, which will be developed in COMMON SENSE.

II. RELEVANT MARINE ENVIRONMENTAL THREATS

Most of the sensors for marine monitoring are expensive and sophisticated. Although some of them may cost only a few dollars, typical costs are much higher, to thousands and more, according to the functions that they have to perform. Generally inexpensive sensors include pressure ones, which can give approximate depth, photo-diodes and thermistors that measure ambient light and temperature. In contrast, specialized sensors include flourometers that estimate concentrations of chlorophyll or hydrocarbon pollution, devices to measure water oxygen or CO2 concentrations, light transmission or turbidity, and acoustic sensors like sonars, to detect underwater objects or doppler current-meters. Such specialized sensors can be much more expensive than basic sensors. Moreover traditionally marine biology and oceanography studies rely on samples that are collected in-situ and require a subsequent laboratory analysis, either on an oceanographic vessel or in a specialised centre on land. So conventional marine research is required to place instruments, laboratories and specialised personnel on site, which means a considerable cost as compared with similar studies on land. For this reason, a new generation technology for cost effective, low power consumption, automatic and low maintenance micro- and nanosensors, able to be installed in a wide range of platforms, not only oceanographic vessels, can help in achieving a better understanding of the seas and promote specific sea studies. Micro and nanosensors (chemical and mechanical) could be described as being composed of a sensitive part which, on interacting with the surrounding environment, collects and concentrates molecules and structural elements at or within the surface undergoing physical changes, and of an opportune transducer that converts into an interpretable and quantifiable term such modification of the sensing part. The heart of the sensor is the sensitive element which is the interface between transducer and external environment so that the nature, the selectivity of the sensor depends upon these interactive materials. The list of most promising materials for micro- and nanosensors includes polymers, ceramics, metals, nano-structured materials and nanocomposites, molecular sieves, sol-gels, biomaterials and their combinations. Therefore, for their design, development and performances, proper and detailed physical, chemical and structural characterization of the used sensing materials are essential.

A short description of the environmental threats, for which the sensors of microplastic, eutrophication, concentrations of heavy metals, underwater noise, and other parameters such as temperature and pressure will be developed during the project, follows.

A. Microplastics (relevant to descriptor 10 of the MSFD)

Microplastics are small plastic particles and have become a paramount issue in the marine environment. Not unequivocally defined, some studies [7] refer to as microplastics all plastic particles smaller than 1 mm pertaining to their microscopic size range, while others [8, 9] define them as smaller than 5 mm recognizing the common use of 333 µm mesh Neuston nets for field sampling.

Fig. 2. Microplastics are tiny bits of plastic that often originate from beach litter — Image source: http://greenjaydigital.com/danniellesgreen/research/microplastics

The abundance and global distribution of microplastics in the oceans has steadily increased over the last few decades with rising plastic consumption worldwide [10]. Then experiments sampling wastewater from domestic washing machines demonstrated that a large proportion of microplastic fibers found in the marine environment may be derived from sewage as a consequence of washing of clothes. As the human population grows and people use more synthetic textiles, contamination of habitats and animals by microplastics is likely to increase [7]. Microplastics are not as conspicuous as larger plastic items, but particles of this size are available to a much broader range of species and have been shown to be ingested by deposit-feeding lugworms (Arenicola marina) and filter-feeding mussels (Mytilus edulis; see [11] and [12]) to name just two examples. Ingestion of microplastics by species at the base of the food web causes concern as little is known about its effects [8]. It remains unknown if microplastics may be transferred across trophic levels. Furthermore, plastic particles may highly concentrate and transport synthetic organic compounds (e.g. persistent organic pollutants, POPs) commonly present in the environment and ambient sea water on their surface through adsorption [13]. Evidence [14, 15] suggests microplastics to be a potential portal for entering food webs for POPs. Of further concern, additives added to plastics during manufacture, may leach out upon ingestion, potentially causing serious harm to the organism. Endocrine disruption by plastic additives may affect the reproductive health of humans and wildlife alike [15]. At current levels, microplastics are unlikely to be an important global geochemical reservoir for POPs such as PCBs, dioxins, and DDT in open oceans. It is not clear, however, if microplastics play a larger role as chemical reservoirs on smaller scales. A reservoir function is conceivable in densely populated and polluted areas, such as bights of mega-cities, areas of intensive agriculture and effluents flumes. Oil based polymers ('plastics') are virtually non-biodegradable. However, renewable natural polymers are now in development which can be used for the production of biodegradable materials similar to that of oil-based polymers. Their properties in the environment, however, require detailed scrutiny before their wide use is propagated. Microplastics are both abundant and widespread within the marine environment, found in their highest concentrations along coastlines and within mid-ocean gyres. Ingestion of microplastics has been demonstrated in a range of marine organisms, a process which may facilitate the transfer of chemical additives or hydrophobic waterborne pollutants to biota [16, 17, 18]. Harrison [19] tried to separate synthetic microplastics (5-mm fragments) from sediments, while with COMMON SENSE we will try to measure microplastics floating in the water.

B. Eutrophication (relevant to descriptor 5 of the MSFD)

Eutrophication is referred to as an increase in the rate of supply of organic matter to an ecosystem [20]. Eutrophication includes a number of processes whose rate changes following an increase in nutrient inflow to a coastal ecosystem. The increase in nutrient inflow may be either natural or anthropogenic, the latter being related to land clearing, production and applications of fertilizer, discharge of human waste, animal production, and combustion of fossil fuels [20]. In recent decades, increased anthropogenic inputs of nitrogen and phosphorus have led to severe eutrophication problems in many coastal areas worldwide, inducing higher phytoplankton primary production [21]. On the other hand, eutrophication and increased turbidity of the water can severely reduce light availability in the water column, affecting benthic communities and causing a shift from macrophyte-dominated environments to phytoplankton-dominated ones [22, 23]. This can lead to significant changes both in the structure and function of the affected ecosystems. The process of eutrophication also increases the frequency and intensity of phytoplankton growth which can generate anoxic conditions. These modifications may have far-reaching consequences, such as fish-kills, interdiction of shellfish aquaculture, loss or degradation of sea grass beds and smothering of benthic organisms, with significant economic and social costs [24]. Moreover, one of the effects of eutrophication is the development and persistence of harmful algal blooms (HABs), caused both by toxic and nuisance algae. In parallel, a trend of cell size reduction in phytoplankton composition has been signalled in a wide range of aquatic environments in the last few decades, suggesting that it can be one of the phytoplankton's responses to global climate change [25]. Chlorophyll-a (chl-a) and phytoplankton, together with nutrient concentrations, are major variables proposed by the European Environmental Agency [26] as indicators of water quality and trophic status. Comparison of anthropogenic nutrient loading with natural background concentrations is also a valuable tool for pressure assessment in the context of Descriptor 5 of the MSFD, this being aimed at minimising human-induced eutrophication. Long-term investigations and comparisons at the eco-region level will be crucial for understanding whether the observed dynamics are mainly locally determined or whether they could be partially driven by global changes. The marine regions and sub-regions considered by COMMON SENSE are all affected to varying extent by eutrophication problems [27]. In the Baltic Sea, from the 1960s to present time, improvements in chemical contaminants have resulted in improvements in the health of top predators, but eutrophication and hypoxia are still widespread. In the North Sea, nutrient discharges causing eutrophication and hypoxia have declined in the last 25 years but problem areas exist seasonally within larger river plumes, particularly in eastern waters. Eutrophication can alter phytoplankton species composition and cause seasonal hypoxia particularly within bottom waters in strongly stratified areas. Benthic community composition will be shaped either by direct mortality or by increasing the vulnerability to predation of less tolerant taxa. Direct and indirect effects often act synergistically, causing shifts in habitat use and modifying trophic cascades with complex results [26]. In the Mediterranean Sea marked differences occur among different subregions. In the Western Mediterranean, land-based pollution may result in the enrichment of the marine environment both in nutrients and in organic matter. The former can cause eutrophication in the water column, while the latter reduces the depth of the redox potential discontinuity in sediments. On the contrary, Eastern Mediterranean waters are characteristically oligotrophic [28] with the exception of the Adriatic Sea

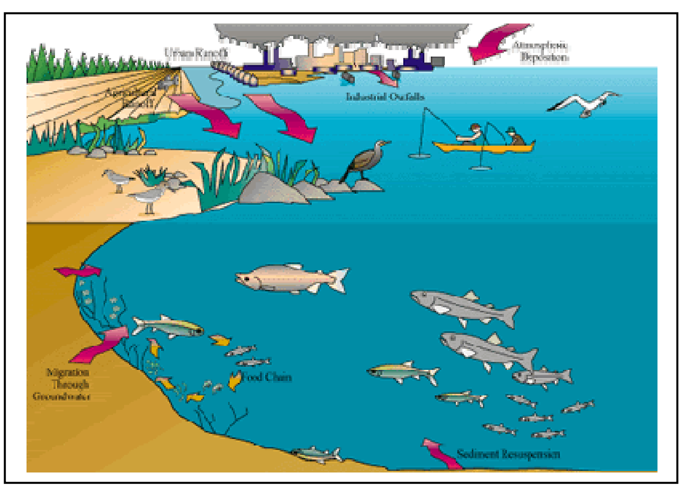
C. Heavy metals (relevant to descriptor 8 of the MSFD)

Heavy metals are members of a loosely defined subset of elements that exhibit metallic properties. It mainly includes the transition metals, some metalloids, lanthanides, and actinides. Many different definitions have been proposed but no consensus of exact definition exists due to a lack of a "coherent scientific basis" [29]. Motivations for controlling heavy metal concentrations in gas streams are because they pose a danger for health or for the environment. Some are carcinogenic or toxic, affecting, among others, the central nervous system (manganese, mercury, lead, arsenic), the kidneys or liver (mercury, lead, cadmium, copper) or skin, bones, or teeth (nickel, cadmium, copper, chromium) [30].

Heavy metal pollution can arise from many sources but most commonly arises from the purification of metals. Unlike organic pollutants, heavy metals do not decay and thus pose a different kind of challenge for remediation.

Plants, mushrooms, or microrganisms are occasionally successfully used to remove some heavy metals such as mercury. Anthropogenic metals are mainly carried with air masses from Northern and Central Europe. As a result, metal concentrations in Mediterranean surface waters are higher than in the open ocean, and those of the inflowing North Atlantic Ocean [31]. The marine regions and sub-regions considered by COMMON SENSE are all affected to varying extent by contamination problems [27]. Over the past 50 years there have been substantial inputs of chemical substances into the Baltic Sea via direct discharges from land-based sources (e.g. industrial and municipal wastes), river runoff or draining, atmospheric deposition from local and more distant sources, or due to shipping. As a result, the Baltic Sea ecosystem has become contaminated with numerous substances, including many persistent organochlorines (e.g. DDT, PCB, dioxins) and heavy metals. Meanwhile, the amount of many hazardous substances discharged into the Baltic Sea has been reduced, mainly due to the effective implementation of environmental legislation (e.g. Helsinki Convention), their substitution by harmless or less hazardous substances, and technological developments.

Fig. 3. Bioaccumulation of Heavy Metals — Image source: http://watersome.blogspot.ie/2012/09/bioaccumulation-of-heavy-metals.html



The residence time of chemical pollutants is high because of the persistence of many contaminants, the specific hydrographical conditions (salinity and oxygen gradients) in the Baltic Sea as well as remobilization processes. In the North Sea, the major sources of chemical contaminants are direct-discharges (e.g. sewage outfalls, storm water, oil and gas drilling) and run-off from industrialized, urbanized and agriculture areas which contaminates adjacent coastal habitats [32]. Adverse effects of chemicals present within sediments have been documented on organisms in the North Sea, particularly along shipping routes.

The flows of industrial heavy metals, such as mercury, increased by 300 % between 1950 and 1990, and this trend has only recently been reversed [33]. Spain, France, Italy and Greece are the main contributors to the heavy metal loads in the Mediterranean Sea [34, 35]. In the Western Mediterranean, the Tyrrhenian and Adriatic Seas are believed to be the most impacted regions [36], but high pollutant-load hot spots are quite widely spread along the Mediterranean Sea [27]. Several sensors have been realized in the recent years to check the presence of specific or general heavy metals like PVC membrane electrodes [37, 38, 39], amorphous nitrogenated carbon thin film electrodes [40] or inkjet printed surfaces enhanced Raman spectroscopy (SERS) substrate [41], just mentioning the most recent published on scientific papers.

D. Underwater noise (relevant to descriptor 11 of the MSFD)

Unlike light, which dissipates quickly underwater, sound can travel farther and up to five times faster underwater, allowing animals to communicate over great distances. The differences between man-made noise (as a byproduct of its offshore activities) in the water and environmental noise (usually generated by aquatic animals for imaging, navigation and communication or by natural sources such as breaking of waves or rain) is well described [42]. When sound is generated underwater, it will have a relatively high level near the source. The level of sound is attenuated as the sound propagates away from the source, and at some distance it will decay to the level of the background noise in the ocean. On land, a wide range of measurements have been taken of the noise levels from all categories of man-made noise. Generally however, there is a lack of equivalent information for underwater noise, although as a result of environmental pressures some measurements are now being made of noise from activities related to petrochemical exploration and exploitation. There are three main reasons for this due mainly to the lack, to date, of any clear need for taking measurements except for military applications, but also the difficulty and expense of taking underwater measurements and/or the lack of any well established criteria by which any measurements taken could be judged. The information on man-made underwater noise may be divided into 5 categories covering activities of shipping, pile driving and construction, sonar and related research equipment, underwater explosives and blasting, offshore oil exploration and production. On internet it is possible to find recent publications on the theme divided by the type of manmade source of underwater noise, especially on the effects on cetaceans. (an example on [42]).

I. THE NEW SENSORS AND TESTING ACTIVITIES

In the framework of the COMMON SENSE European project several type of sensors are being developed and then tested on board of research vessels or other platforms like drifters, deep and shallow water moorings, surface buoys, oil platforms, etc. Here a short description of the new sensors is provided. Sometimes descriptions are incomplete as the project is at half of its life during the preparation of this manuscript and changes can still occur, particularly after testing activities of sensors prototypes planned in the third year of the project. In order to start acquiring information on sensors and validation procedures at eight months from the beginning of testing activities two tables have been prepared and filled in by each actor, sensors developer or tester.

A. Microplastics

Two partners are developing sensors for microplastics: one has designed a sampling system consisting of three main elements: optical transducer including imaging (multi-spectral camera) and excitation sources (IR light); control board including processor for data acquisition, pre-processing and conversion to required transmission format; sampling system able to collect water samples from water surface. Sensor operation will be automated as much as possible to minimize human operation. Water samples will flow through a transparent channel where microplastics concentration will be measured using an optical sensor. Currently, main installation difficulties are related to coupling sensing system and water sampling system, but in some cases, the sensor could be placed directly in water (so that a sampling system is not needed). Main information given by the system is the surface microplastic concentration in mg/litre. Additional discrete sensors are included in the sampling system (turbidity, florescence, CTD, pH, DO). Sampling frequency will be set at 30 minutes. Real time data could be transferred only if required technology is incorporated in the platform. The second partner is developing a system based on Niskin bottles associated with the microplastics analyser. It can be deployed down to a max of 100 m. The sampling system is completed with pressure, conductivity, salinity, temperature, pH, O2, CHL-a and turbidity sensors. The system does not need any particular vessel for installation. However, due to its weight, when the Niskin bottles are full of water, the best solution is the use of a small winch (available on research vessels). The data acquired can be stored by the water sampling system in the internal memory or transmitted.

B. Eutrophication and pH/pCO2 (relevant to descriptor 5 of the MSFD)

The sensor for eutrophication are meant to be used in surface waters (0-3 m depth). The targeted maintenance interval is 1 month – implying that the storage capacity of reagent, calibration and waste storage containers will be sufficient for this period. Sensors operate using battery power, which may need to be supplemented by energy harvesting, e.g. using solar panels on buoys. Data can be stored by flash memory chips or removable memory (e.g. SD cards). Data storage is required on the platform regardless of deployment scenario to provide data redundancy; e.g. in the event of communications failure. Possible means of data transmission include satellite, GSM, Wifi/Wimax, short range transmission such as ZigBee, BlueTooth, or via directional antennae in function of the deployment location. The data transmission mode is determined by the deployment location and the local transmission coverage. Possible platforms for deployment of the sensors include research vessels, buoys, underwater moorings, ocean racing yachts, fishing vessels or other vessels of opportunity. The primary output data is nutrient concentrations. The raw data is transmitted in the form of a series of light intensity readings. Each measurement also includes a temperature reading and a date stamp. Data storage capacity is determined by the selected mode of storage – e.g. 16 Gb for SD card, megabyte range for flash memory chips. Due to the small size of data generated for each individual measurement, this is not expected to represent a significant limitation. Data logging can be used if sensors are to be deployed in scenarios where none of the possible transmission modes are available. Raw data is transmitted in the form of a series of light intensity readings and need to be initially converted to absorption values, and then to concentration values.

The final data to be stored and displayed is in the form of nutrient concentrations. Raw data also provides additional information on sensor performance and allows cross-referencing with data stored on board the sensor (e.g. allowing reliability of transmitted data to be validated). The data management system should also allow for additional features such as event detection, event classification (identification of false positives/negatives) and data smoothing (for display purposes). The nanosensors for autonomous pH and pCO2 measurements is also designed for deployment in surface waters (0-5 m) as those for eutrophication. Their maintenance interval will vary depending from sampling frequency. The sensors will be probably ready by August 2015. Over 400 commercial electrodes are available so several types of sensors based on PANI/Graphene and PANI/MWCNT nanostrucutures will be realized in order to extend application methods, but initial plans are to start with four pieces for each type.

C. pH sensors (linked to Eutrophication)

pH sensors are widely used in chemical and biological applications such as environmental monitoring (water quality), blood pH measurements and laboratory pH measurements amongst others. The earliest method of pH measurement was by means of chemical indicators, e.g. litmus paper that changes its color in accordance to a solution's pH. For example, when litmus is added to a basic solution it turns blue, while when added to an acidic solution the resultant color is red. Since many chemical processes are based on pH, almost all water samples have their pH tested at some point. The most common systems for pH sensing are based upon either amperometric or potentiometric devices. The most popular potentiometric approach utilizes a glass electrode because of its high selectivity for hydrogen ions in a solution, reliability and straight forward operation. Ion selective membranes, ion selective field effect transistors, two terminal microsensors, fibre optic and fluorescent sensor, metal oxide and conductometric pH-sensing devices have also been developed

[43]. However, these types of devices can often suffer from instability or drift and, therefore, require constant re-calibration. Polymers are also used in various sensors for pH measurement [44]. Namely, by introduction of functional groups, polymers can be designed to selectively swell and shrink, resulting in changing mass and elasticity, as a function of analyte concentration. The ion-exchange properties of conducting polymers are of special interest for potentiometric-sensor development [43]. Conducting polymers are ideally suited for sensor applications because they not only exhibit high conductivity and electroactivity but they could also be used as a general matrix and can be further modified with other compounds in order to change selectivity. Compared to conductive polymers, nonconductive polymers usually have a high selective response and a high impedance, which is important for eliminating interference by other electroactive species.

D. *Heavy metals (relevant to descriptor 8 of the MSFD)*

Measurements with the sensor for heavy metals will be performed at surface waters that have to be delivered to the measuring setup after filtration. The needed volume is very small (well below 1 ml). The power consumption of the potentiostat and microfluidic pumps is estimated to be below 1-2 W. The sensors do not need maintenance since they are single use and an array of them will be available for different measurements. The fluidic system might need maintenance against fouling. The sensor is aimed to be fully automated and therefore low power consumption, in order to be powered by batteries. Sensors will be tested on board research vessels, where water sampling devices are available (wet lab). Data can be stored in USB memory or transmitted by internet after measurement. This sensor needs several containers: A) two liquid reservoirs with two types of buffer solutions (typically below 1 L each) for conditioning the sample at the pH needed for the analysis of the different heavy metals; B) eventually, three containers with standard solutions of different concentrations for each the heavy metals under study, of typically 20 ml each, if the standard addition method is used (i.e. 3X5=15 containers of 20 ml); C) an additional container to collect the residual liquids containing heavy metals. Regarding the output data (acquisition frequency is about 20 minutes), one raw measurement consists of two columns of ASCII data containing values of Current Intensity and Voltage. The temperature of the measured liquid and the measurement date should also be included in the file (less than 20 kb altogether). In case of using the standard addition method, each measurement would additionally generate three more of these files. Data can be transferred in real time via internet or at the end of the cruise when they must be processed.

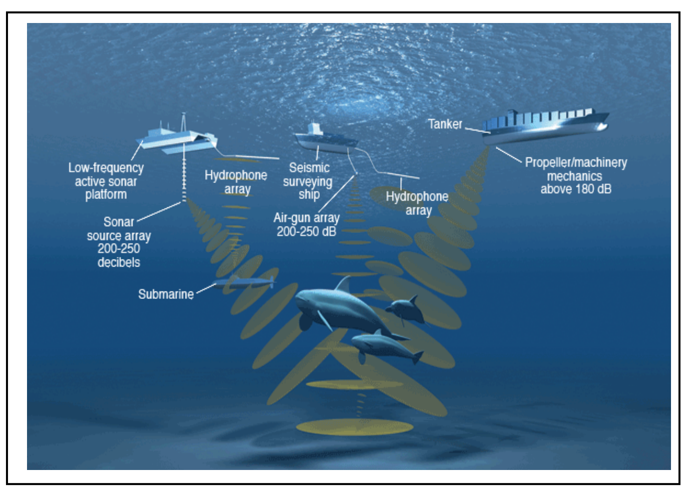
E. *Underwater noise (relevant to descriptor 10 of the MSFD)*

Two partners have proposed sensors for underwater noise. One of them is developing a sensor to be used only near the surface (0-5 m), to be deployed/installed using low noise methods (e.g. fixed quiet moorings or maybe also on drifting buoys). It offers the possibility to transmit short packets of data or a summary of them. Data type produced, which must mostly be processed within the unit, describes sound pressure over time (voltage vs time). The frequency is initially 25 kHz, but potentially up to 192 kHz. The second partner proposes a sensor for underwater noise that can be installed on a hydroacoustic buoy deployed at depths down to 100 m and has an autonomy of up to 1 month. The weight is about 160 Kg, so it can be put at sea only with a ship crane (with a suspension arm > 6 m and a lifting capacity > 5000 N). The unit can be recovered with rough sea states (> 4 Beaufort). Data is stored in the SD memories but it is possible also to install a WIFI channel and download all the data at the end of the experiment. Data types are acoustic pressure time series (frequency depends on the hydrophones installed, usually they sample at 30kHz in each of the four channels) and they must be processed. The output is an acoustic pressure time series, in frequency range from 5/100 Hz up to 12 kHz. Final parameters are: Noise spectrum level, statistics of momentary values acoustic pressure of the noise. Possible platforms for testing the sensor are research vessels in the Mediterranean, the Baltic Sea and the North Sea.

F. *Piro and piezo resistive polymeric temperature and pressure sensors*

The innovative piro and piezo resistive polymeric temperature and pressure sensor proposed does not need any maintenance since it will be inside a small container and the material is stable for years. Periodically, it must be calibrated to assure that the entire device, including the sensing material, is properly working. Measurements are directly performed by immersion into the water. It can be installed in any platform, since the power needed for the measurement is very low. Data can be stored in USB memory or transmitted by telemetry. The output of one raw data consists of two/four columns of ASCII data containing values of time/data and resistance/temperature (if the calibration of R(T) will be included in the device processing before acquisition). The measurements can be continuous or planned for a specific period of time. The transfer to the data centre could be made in real time by satellite or internet or at the end of the experiment. Data, after calibration, does not need to be processed.

Fig. 4. Marine noise pollution - —Image source: http://www.marineinsight.com/marine/environment/effects-of-noise-pollution-from-ships-on-marine-life



II. Conclusions

Sensor networks are collecting tremendous amounts of different environmental data. As sensor technologies are improving and becoming cheaper, more and more will follow in the future. Conventional underwater sampling and research has assumed the cost of traditional sampling methodologies (sample return and/or scientist onsite), which tend to be expensive and in addition are not sustainable in time. Therefore, the use of in-situ new generation sensors as well as the integration of these sensors in different marine platforms will be necessary in order to reduce sampling and monitoring costs. The COMMON SENSE sensors, developed onto modular systems, will be integrated into multifunctional packages.

TABLE I. SENSORS AND AVAILABLE PLATFORMS FOR TESTING ACTIVITIES. ABBREVIATIONS = E: EUTROPHICATION; M: MICROPLASTICS; H: HEAVY METALS; U: UNDERWATER NOISE (2 SENSORS); TP: INNOVATIVE PIRO & PIEZO RESISTIVE POLYMERIC TEMPERATURE & PRESSURE SENSORS; N: NANOSENSORS FOR PH & PCO2

SENSORS ------------------------ PLATFORMS	E	M	H	U1	U2	TP	N
R/V Urania	V	V	V		V	V	
R/V Sarmiento De Gamboa	V	V	V	V		V	
R/V Oceania	V	V	V		V	V	
Motorboat	V	V	V		V	V	
Oil Platform	V					V	V
Oil Platform in Gdansk Bay	V	V	V		V	V	V
Smartbuoys				V			
Mediterranean Deep Moorings	V	V				V	
NW Mediterranenan deep continental moorings			V			V	
Aqualog	V		V			V	
OBSEA observatory	V		V			V	
Ocean Racing Yacht – IMOCA, Open 60 boats	V	V					
Expendable ocean instruments, Drifting Buoys	V	V	V			V	V

Moreover, innovative transversal sensors (temperature, pressure, pH, conductivity and pCO2, among others) based on cost effective “new generation” technologies for the continuous monitoring of water parameters will be developed. The integration of these transversal sensors will provide variables measurement with a reference frame (time, position, depth, temperature, etc.). It will also be necessary to have a complete understanding of the properties of sensing materials in order to ensure the performance of the micro and nanosensors developed. In this sense, an effort will be done to study the design and development of nanocomposite films aimed for cost-effective sensor. The developed sensors will be interoperable with existing and new observing systems and they will also be field-tested by means of autonomous platforms and opportunity vessels (see Table 1 for platforms from project partners). In addition to the implementation of the Marine Strategy Framework Directive, the tools provided by the project will also support other European Maritime and Environmental Policies. A feasibility analysis will be carried out in order to ensure that the sensors developed within the frame of the project are operative and able for a large-scale production and a widespread use. The field testing activities of the innovative sensors will be realized through the use of research platforms like research vessels, oil platforms, drifters, deep and shallow water moorings, etc but also with the involvement of stakeholders (including cooperation issues). Then the data acquired from the new sensors will be verified through comparative measurements. We hope that the extended use of these developed sensors will provide an increase in the temporal and geographic coverage from in-situ data on eutrophication, heavy metals, microplastics and noise sensors to enhance European monitoring of the marine environment. This should allow a reduction in the cost of standardized data collection making marine observation data available and suitable for integration with existing observing systems.

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