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To cite this article: R Abualhajja *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **899** 012045

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# Participatory process in environmental monitoring design: examples from the Port of Limassol

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**Abstract.** Sea transport and seaborne trade have increased significantly in the past few decades. As sea traffic hubs, ports have high risks because of the limitation in manoeuvrability, number of vessels, and land-based port activities. In the coastal city of Limassol, water and air pollution has been anecdotally attributed to port activities. The STEAM project (Sea Traffic Management in the Eastern Mediterranean, INTEGRATED/0916/0063, [1]) aims to set up a monitoring plan to aid in the identification and mitigation of pollution sources. The project followed a participatory process, where port stakeholders and scientists were consulted and included in the ideation, design and implementation process. This participatory process developed a greater sense of stakeholder ownership in the environmental monitoring programs and facilitated their adoption. According to the consultation process, air and water quality are the most important factors to monitor. Five static and one mobile multi-sensor monitoring stations make up the air quality monitoring design for the Port of Limassol. Three air quality stations were installed within the port area along with two stations near the anchorage area. Two environmental data buoys and two oil detectors make up the water quality monitoring stations. The oil detectors will be placed within the port. One environmental data buoy will be placed downstream of the port, while the second buoy will be placed between the port entrance, the Limassol Marina and the anchorage area.

## 1. Introduction

Coastal water pollution has been partially attributed to port operations in areas such as Trieste, Italy, and Aden, Yemen [2]. There are multiple issues concerning the impact of ports on the environment and more specifically the pollution of the sea due to maritime accidents (e.g., oil spills) or illegal ship waste, as well as air pollution through ship emissions that must be controlled. All these factors combined, lead eventually to huge economic costs to the related ports and authorities, but also to shipping companies and other related stakeholders. Continuous monitoring of ports can help identify the sources of pollution and a measure of the effectiveness of environmental measures.

The United Nations Economic Commission for Europe adopted in 1998 the involvement in decision-making for environmental issues as part of the democratic right in the Danish city of Aarhus. There is also growing evidence that the participation of stakeholders in environmental monitoring can have positive societal and benefits in environmental programs [3]. At the same time the organisation



of the participatory process and the level of engagement need to be well thought out to assure the quality and long-term value of the initiative [4].

There are several ways to identify and monitor pollution in a port including fixed point stations and mobile sensor platforms. Buoy systems are marine fixed-point data collection platforms. The platform can be customized with a unique array of sensors to fit the purpose of the project at hand. Buoys have the advantage of having low maintenance costs and the ability to transmit real time data to a land station. They are constricted though by the available space on the buoy for the attachment of sensors, and the power available for their operation and data transmission, making the design stage key to the success of the monitoring system. Fixed stations also include land-based sensors for water quality that can be attached to piers and fixed seaside structures and atmospheric pollution stations. Being on land means these stations are readily accessible for inspection and modification and have easier access to power for sensors and processing units and Wi-Fi for data transmission. Multiparameter and oil sensors are ideal for port water quality monitoring. Multiparameter sensors are usually compact and customizable to collect information on several parameters at once such as turbidity, salinity and chlorophyll-*a*. Oil sensors are integral for monitoring oil spills and port operations. These systems often have a built alarm system to alert the authorities of unusually high concentrations of oil in the water. Air quality in a port area is usually monitored by fixed stations. Improvements in sensing technology have generated compact multiparameter devices that are nearly autonomous and can provide near-real time data.

These water and air quality stations collect data from fixed points over a long period of time. The temporal scale is important for monitoring programs for the study of long-term pollution trends and specific events. Nevertheless, they run the risk of not identifying the source of the pollution due to their narrow spatial coverage. Unmanned vehicles are versatile platforms that enable long-range operations often covering wider spatial scale. Autonomous surface vehicles can be used to monitor water quality and port traffic. Although historically these platforms have been quite hefty, new technology has given rise to small, nearly indestructible vehicles that could operate within the port and in the offshore area surrounding it. Unmanned aerial systems could be used for air quality monitoring. Both these systems offer the manoeuvrability needed to run selected routes repeatedly to collect a long term data-set and also reach and collect data from potential pollution sources. The increased survey duration, mission safety, and repeatability offered by unmanned vehicles is countered by the limited payload of the platform that needs to be carefully assigned to fit the desired sensing devices, power supply and communication system.

Although there are several common points among ports, each port has its unique characteristics that must be taken into consideration upon designing an environmental management plan. For example, the port of Limassol was built on the east side of the city of Limassol, between the Limassol Marina and the Sovereign Base Areas of Akrotiri and Dhekelia, a British Overseas Territory on the island of Cyprus. To the north of the port lies the city's industrial area. In addition, with the expansion of the city, the port is also surrounded by businesses and residential buildings. The surrounding area is not only impacted by possible pollution caused by the port but, in some cases, may also be the source of pollution. Therefore, the location of the monitoring devices should be such that the respective sensors accurately identify the sources of pollution.

Pollution alongshore of Limassol has frequently been a cause of concern. Toilet waste, garbage and other particles have been found washed up onshore at popular bathing and touristic areas. The problem has been so intense in the past years that the municipality has commissioned a servicing company to clean up the area [5]. It is suspected that the pollution originates from vessels traveling towards the port or in the anchorage area despite some evidence that pollution originates from restaurants next to the port and the city itself. However, recent evidence concerning the presence of oil mixed with the waste suggests that the pollution originates indeed from vessels [6].

## 2. Method

There are different ways to involve the community in an issue. One is through collecting data and opinions, where the general public is asked to give its opinion for a specific problem [7-10] or have an input on decision making [11]. In other cases, only the stakeholders, which are more closely related to this area and/or problem, participate in this process [3]. For the design of the environmental monitoring of the Port of Limassol a stakeholder consultation process was followed. The stakeholder consultation process was divided into three phases to define the main concerns and monitoring goals. The first phase included desktop research of the state of the art in port environmental monitoring and a relative discussion with the stakeholders. During the second phase, we conducted an online survey and one-on-one meetings with key stakeholders to set the environmental monitoring priorities for the Port of Limassol. After the ideation and design stage, the group discussed the implementation logistics of the Limassol Port environmental monitoring.

### 2.1. Ideation and presentation of port monitoring state of the art

We conducted an in-depth research on the state of the art of port environmental monitoring, local and regional practices, and relevant legislation. We then presented this research to port stakeholders to spark the ideation session. The presentation included the systems available, such as buoys, sea surface vehicles, autonomous vehicles, and fixed-point data collectors. The presentation covered each method as well as their advantages and disadvantages. The presentation was followed by a discussion on the priorities for the Port of Limassol. All participants engaged in the discussion and provided specific and experienced insights on the operations of the port and the historical collection of environmental data. In some cases, opinions diverged and, in some cases, clashed. These were noted and taken into consideration in the design of the monitoring plan.

### 2.2. Online survey and in-person interviews

Based on input from the first step, we created an online survey with five questions. The questions revolved around the stakeholder priorities, environmental parameters, the spatial and temporal extent of the monitoring program as well as the data delivery process. The online survey used the line app Zoho Survey, which is part of the Zoho suite of cloud applications (Zoho Corporation Pvt. Ltd, Chennai, India). It was published in May 2019, and it remained active for two weeks. The web application notified stakeholders registered through the STEAM network to participate in the survey process. The application also sent a reminder after the first week. In addition to the online survey, meetings with key personnel were also scheduled.

### 2.3. Presentation of results and consultation on design and implementation

Guided by the outcomes of the online survey and in-person meetings, we presented and facilitated a discussion about the appropriate port monitoring options. The applications and technologies presented included various monitoring platforms such as unmanned aerial vehicles (UAVs, commonly known as drones), the Sailbuoy (an automated water surface unmanned vehicle) and fixed environmental buoy systems.

Following the presentation, participants engaged in a fruitful discussion regarding current efforts to monitor air and water quality. Several authorities and companies engaged in the port operation offered suggestions regarding next steps for port environmental management.

## 3. Results

### 3.1. Stakeholder consultation process

In total, the design of the environmental monitoring plan for the Port of Limassol was discussed in two in person and one online meeting. The meetings took place at the port and online (during the Covid-19 pandemic) to suit the availability of the stakeholders. The meetings were well attended by port stakeholders (companies implicated in the port operation such as Eurogate Container Terminal

Limassol Ltd and DP World Limassol), relevant authorities (such as the Cyprus Ports Authority and Cyprus Shipping Chamber) as well as the researchers and professionals from the STEAM consortium. The meetings ranged between two to three hours of which 30-40minutes were dedicated to the environmental monitoring plan. The application also sent a reminder after the first week. The application also sent a reminder after the first week.

The online survey collected fourteen completed responses (out of 48 online survey visits, Table 1). Respondents represented nine companies and institutions (Cyprus Shipping Chamber, DP World Limassol, Eurogate Container Terminal Limassol Ltd., Cyprus Shipping Association, Cyprus Port Authority, Cyprus University of Technology, Maritime Institute of Eastern Mediterranean, P&O Maritime Cyprus, and monitoring plan are solid waste disposal, plastics, and hydrocarbons. The areas to be monitored primarily are those that lay within the port, including the anchorage area, and offshore from the Port of Limassol (64.29%), preferably from an extended area, rather than a fixed point or transect. Stakeholders would like to see monitoring data being transmitted and visualised in real time. The question that had the most resounding result (71.43%) reflected the need of the port stakeholders to maintain the environmental monitoring program beyond the lifetime of the STEAM project.

Three in-person interviews with key stakeholders were concluded. Katerina Dokou, the Environmental Officer of the Cyprus Port Authority, offered insight regarding the historical and ongoing environmental monitoring at the port of Limassol. She detailed the present requirements for pollution mitigation actions, cleaning procedures and accident response plans. We also discussed what are the expected future challenges in the port and what how can the STEAM project contribute to a better environmental management plan. Mr. Stelios Colombos, currently a VTS operator at the port of Limassol, also contributed greatly to the definition of the implementation plan for water and air monitoring. Together we discussed the possible location of buoys and air quality stations. Mr Colombos provided guidance for the implementation process regarding acquiring permissions to set-up monitoring equipment in the area. He highlighted the need to include oil sensors in the vessel docking area and the set-up of a future weather station near the port. Petros Dias, the Health Safety Security Environment Manager of Eurogate Container Terminal Limassol Ltd, also expressed interest in installing air quality stations measuring dust at the port terminal and was consulted regarding the design and location of the monitoring systems.

**Table 1.** Distribution of participation in the online survey per organisation.

| <b>Organisation</b>                         | <b>Number of participants</b> |
|---|-------------------------------|
| Cyprus Shipping Chamber                     | 1                             |
| DP World Limassol                           | 2                             |
| Eurogate Container Terminal Limassol Ltd.   | 1                             |
| Cyprus Shipping Association                 | 1                             |
| Cyprus Ports Authority                      | 4                             |
| Cyprus University of Technology             | 2                             |
| Maritime Institute of Eastern Mediterranean | 1                             |
| P&O Maritime Cyprus                         | 1                             |
| Cyprus Subsea Consulting & Services Ltd.    | 1                             |

### 3.2. Environmental monitoring network

Through the survey and meetings, the consortium's plan converged towards a monitoring design that utilises a diversity of approaches to capture water and air quality within and around the port (Figure 1). The stakeholders of the Port of Limassol agreed on the need to monitor pollution, solid waste, and plastics and requested access to the status and state of the sea in real time. Taking into consideration

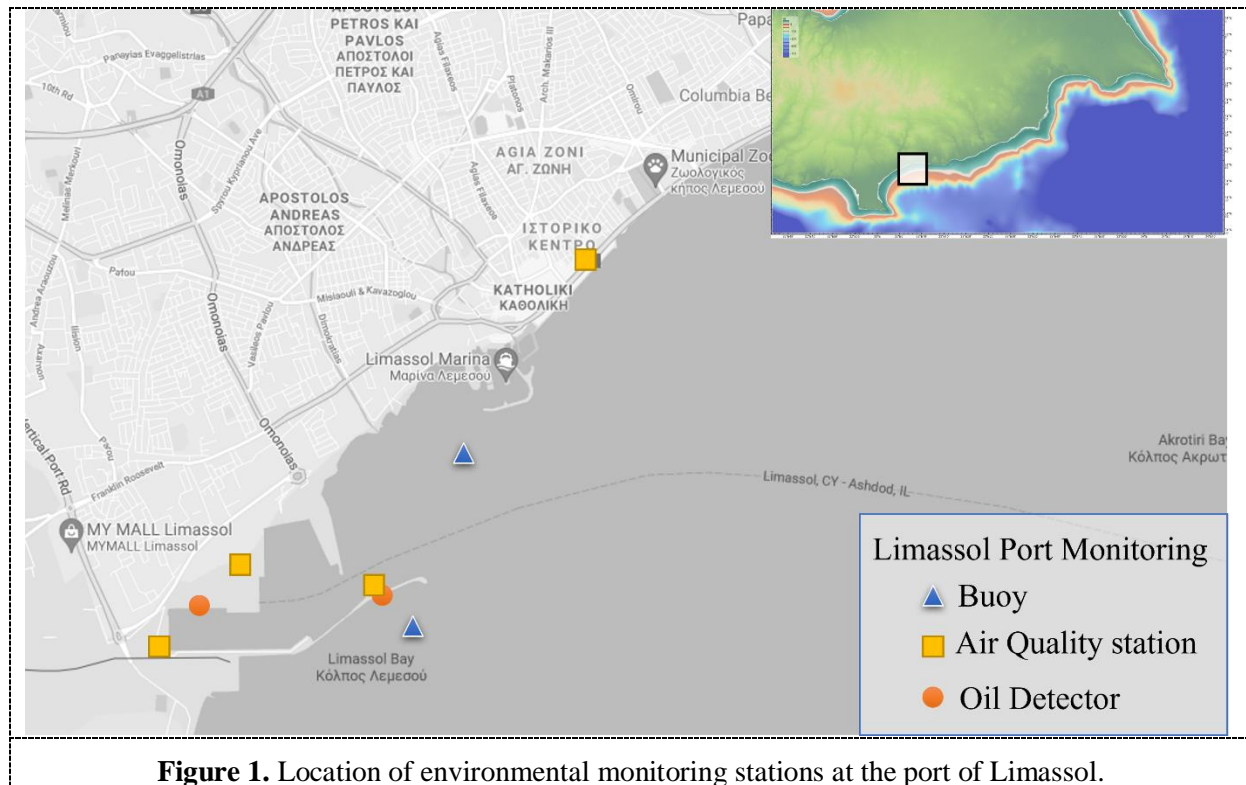
the project's logistics and available funds, the design aims to maximize the collection of requested data whilst making information readily and easily available to users. The design blends analysis on readily available environmental information and the collection of in-situ data.

Online data repositories are valuable resources. Earth data products are produced through various approaches such as modelling based on satellite collected data and forecasting algorithms. Several variables are available through these resources with different spatial and temporal variability. For this project, the most serviceable set of variables were incorporated in an online tool that downloads, processes and offers the access to mapped data and options to view and download data in different formats [12].

Water quality will be monitored through two fixed buoys. One buoy will be deployed south of the port, while the second buoy will be installed between the port entrance, the Limassol Marina and the anchorage area. The buoys will be equipped with sensors to monitor chlorophyll-a concentration, dissolved oxygen levels, turbidity and CDOM. Temperature and salinity sensors will provide background information of the state of the coastal area. Hydrocarbon sensing technology will be used in the port's monitoring scheme. Two oil detection sensors will also be installed within the port – one sensor adjacent to the dock and a second sensor by the entrance of the port. Oil detection sensors will also be mounted underneath the two buoys.

Temperature, humidity, pressure, CO, NO<sub>2</sub>, SO<sub>2</sub>, O<sub>3</sub> and PM<sub>10, 2.5, 1.0</sub> are monitored through the fixed air-quality stations. Three of these stations are within the port area and another two are located near the anchorage area. In addition, a custom-made mobile, fixed-wing unmanned autonomous vehicle has the capability of monitoring temperature, humidity, pressure, CO, NO<sub>2</sub>, SO<sub>2</sub> and O<sub>3</sub> in the port and anchorage area.

All the environmental monitoring systems including air quality monitoring stations, data buoys and oil detection stations, will transmit data in real-time to the STEAM environmental monitoring platform for storage and analysis purposes. The platform currently displays information collected from the air quality and meteorology stations [13], while data from buoys and oil detection sensors are also expected to be integrated in the near future. The platform will offer real-time information on water and air quality, as well as data analysis capabilities and alerts, such as early warnings for oil spills. In addition, the data and several analytics will be available to STEAM members, port operators, and the wider public through the online Ocean Data Interface.



**Figure 1.** Location of environmental monitoring stations at the port of Limassol.

#### 4. Discussion

A system for collecting environmental monitoring data related to oceanographic parameters, water quality, and air pollution has been implemented in the STEAM project. This involves: (i) data integration from existing sources, (ii) fixed land and sea stations and (iii) a UAV with appropriate sensors for collecting air-pollution data autonomously.

The final design of the environmental monitoring at the Port of Limassol stems through a systematic participatory process. Persons who hold a stake, are affected by, or can affect the decision, were engaged in the process. Frequent meetings allowed for the definition of the project goals, the exchange of ideas, reflective deliberation, mitigation of issues and adaptation of the design. Stakeholders were also informed of the implementation progress of the project goals and offered a platform to voice suggestions and concerns through all stages.

The participatory approach encourages the feeling of democracy, autonomy and increased responsibility towards the environment. Hart [14] goes as far as stating that participation in environmental monitoring should start at an early stage with the involvement of children and young adults. By empowering stakeholders, they gain a higher capacity to use the resulting knowledge and promotes social learning [3]. In addition, it is argued that the participatory process increases the quality of initial inputs and the likelihood that the resulting initiative meets local needs, is more robust and leads to better uptake of information [3].

Nevertheless, there are certain drawbacks that need to be considered when designing a participatory process. These often refer to the quality and degree of participation [15], the stage the stakeholders are invited to participate in, [4] and how researchers utilize the resulting information [16]. The lack of involvement of stakeholders in the ideation and data use stages often hampers participatory environmental monitoring [4]. Many projects claim to be participatory but mainly engage stakeholders and/or the public in the data collection process, such as in citizen science initiatives [4]. These projects fail to empower local communities, and this is often reflected in the low long-term participation rates of the stakeholders [16].

Researchers should also be aware of “consultation fatigue”. The increase in participatory projects has also seen an increase in dissatisfaction among stakeholders [3]. This feeling is increased when their perceived losses outweigh their gains, when they feel that their voice is not heard and in cases where the participatory process delays decisive action [3]. Accreditation of stakeholder contribution is also an important issue since over a third of participatory programs do not report participants through all stages of a project [4].

During this project several best-practices to the participatory approach were implemented following the recommendations made by [3]. Stakeholders were engaged from the onset of the project in an environment that promoted empowerment, equity, and trust. Established relationships and rapport was reinforced through systematic meetings embedded in the process of the STEAM project (“Living Labs”) designed to fit the capabilities of the stakeholders. Finally, the goals of the project were clearly discussed, and decisions were made based on local and scientific knowledge.

## 5. Conclusion

The design of the environmental in-situ monitoring plan at the Port of Limassol stems from background research of the available and emerging technologies, an overview of the methodologies used in ports elsewhere and consultation with port stakeholders. The location of the oil detection sensors will capture the possible release or leak of oil from vessels and help identify the origin of the pollution. The two environmental data buoys will help localize the source of solid waste while air quality stations will increase our understanding of pollution patterns resulting from port activities in the city of Limassol. The participatory process used to design the environmental monitoring plan is meant to develop a greater sense of ownership for the environmental program and a good relationship among STEAM project consortium partners and port stakeholders. The participatory process provides opportunities for everyone to voice their concerns and aims towards the better adoption and implementation of environmental monitoring measures.

## Funding

This work was co-funded by the European Regional Development Fund and the Republic of Cyprus through the Research and Innovation Foundation (STEAM Project: INTEGRATED/0916/0063 and MARI-Sense Project: INTEGRATED/0918/0032).

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