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Implementation of a Pilot Monitoring Plan in Bourgas Seaport

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I. Introduction

The increased human activity and uncontrolled pressure on ports and their surroundings has led to their gradual coastal erosion and environmental degradation [1]. The sustainable development of sea ports is highly dependent on the planning of environmental management policies and strategies which should be based on financial, environmental and social factors in line with the legal frame and technical requirements for each case study. Towards effective planning it is crucial to incorporate environmental monitoring systems [2]. However, even though the Balkan Mediterranean ports have already established integrated systems for environmental management, only a minority of the port authorities are able to operate environmental monitoring systems in terms of efficient cooperation and networking with other port operators and decision makers of the surrounding areas. Thus, the port of Bourgas is inevitable listed under the aforementioned cases.

The Black Sea port, Bourgas (Fig.1) is part of the Trans boarder Corridor 8 and therefore it has been chosen as a pilot site for environmental monitoring in the European projects ECOPORTIL [3], ECOPORT 8 and TENECOPORT [4]

Fig. 1. Port of Bourgas

During the expansion of the port of Bourgas into the sea some of the urban sewage discharges are now falling within the new harbour water area. On these grounds, water quality monitoring of port waters could provide accurate data as regards the identification of the main pollutants affecting the Gulf of Bourgas and consequently the established industry in the surroundings. Moreover, through the integrated monitoring procedures, port managers, decision makers and the relative stakeholders will be also able to embrace effective measures in order to confront with environmental vulnerability of the port and the whole coastal area of Bourgas City. The present paper constitutes an indicative integrated monitoring system case study aiming to improve the quality of Bourgas port through the prevention of pollution and the preservation of natural resources in port areas and the surrounding coastal zones that are pivotal for maritime sustainability.

II. Methods and Results

The monitoring system aims to provide all the necessary information in order to conduct an overall assessment of the changes in the natural environment and the water of the Small Bourgas Bay, resulting from the widespread anthropogenic activities. The results from the preliminary monitoring will enhance the development, optimization and design of the next stage – operational monitoring programme.

The sampling for the preliminary monitoring was conducted with the use of a service cutter. The cutter was equipped with a GPS navigation system and was being positioned at the coordinates of each monitoring point. Sampling performance of each point included two water samples (one from the bottom layers and a second one from 1 meter depth) and one sediment sample.

Water and sediment samples were taken from 23 points: 1,3,4,6 – located in the basin of terminal East; 6,7,8,23 - in the basin of terminal 2A; 9,10,11 – in the basin of terminal Ro-Ro; 12,13,14 – in the basin of Container terminal; 15,16,17,18 – in the basin of private ports; 19 – central city beach; 20 – approach channel; 21, 22 – reference points (outside of the port); 2 – in the basin of the Oil terminal (Fig. 2);

Fig.2. Location of the sampling points in Bourgas Gulf

Each sample was analysed in situ regarding its temperature, barometric pressure, dissolved oxygen (DO), conductivity, ORP, pH, resistivity, specific conductance, and salinity, using the special equipment named as "Professional Plus Multiparameter handheld (with Quadro cable) and ProODO". Then each sample was transferred into a plastic bottle and stored in a refrigerator box for the laboratory analyses.

This kind of in situ analysis aims at defining the risk areas and critical points of contamination of the port waters. The status of the coastal waters in the harbour will be estimated on the basis of the physic-chemical analysis of samples. The parameters and their threshold limit values, which coastal waters must meet, are defined by Regulation No 8/ 2001,[5].

The YSI Professional Plus handheld multi parameter meter provides extreme flexibility for the measurement of a variety of combinations for dissolved oxygen, conductivity, specific conductance, salinity, resistivity, total dissolved solids (TDS), pH, ORP, pH/ORP combination, ammonium (ammonia), nitrate, chloride and temperature.

Laboratory chemical analysis of the water samples from 6 monitoring stations (sample 2 – Oil terminal; sample 5- terminal East /old harbour/;sample 8 – terminal 2A;sample 11 – terminal Ro-Ro; sample 14- Container terminal and sample 22 – point of reference) were carried out in the laboratory of National Institute of Meteorology and Hydrology in Sofia Bulgaria.

The Permanganate oxidation, ammonium, nitrite ions, nitrate and phosphate ions were analysed immediately after shipment with Spectrophotometer DR/2010 HACH.

The electro thermal atomic absorption spectrometry (ETAAS) measurements of heavy metals were carried out using a Perkin-Elmer (Norwalk, CT, USA) Zeeman 3030 spectrometer. A continuous flow (CF) vapour generation accessory (VGA-77, Varian) connected to an atomic absorption spectrometer (SpectrAA 55B, Varian) were employed for HG-AAS measurements of As and Hg. The highest water nutrient loading was the basin of Container terminal (Fig.3).

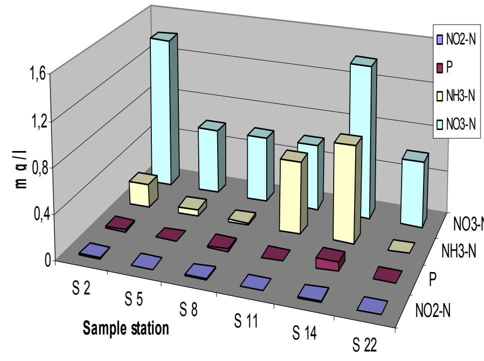

Fig.3. Graphical data interpretation from the analysis of nutrients in the coastal waters of Bourgas Port

The basin of Container Terminal (sample 14) was also affected by the wastewater treatment plant discharges into the port basin through a connecting channel. The basin bottom substratum is a grey-black mud smelling of hydrogen sulfide (H2S) which is the end product of anaerobic biodegradation of detritus which constitutes also an indicator of anoxic conditions in the mud. The high concentrations of NH3-N, as well as the high values of inorganic phosphorus (PO4-3, P2O5, P) are indicative for the eutrophic characterization of the port waters. The levels of heavy metals in harbour waters are under the threshold concentrations (Fig.4), according to the Bulgarian Regulation N0. 8/2001, [5].

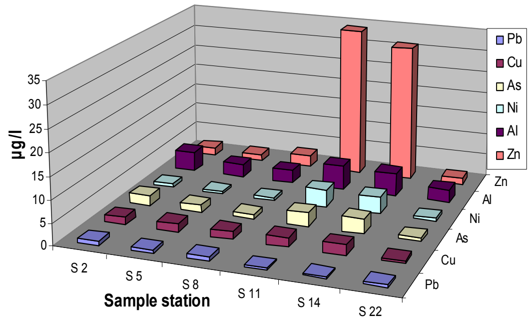

Fig.4. Graphical data interpretation from the analysis of certain heavy metals in the sea water of Bourgas Port

Sediment testing in the port and the Small Bourgas Bay included testing hydrocarbons in the sediments, testing organic matter in the sediments and Bio-testing bacterial phosphatase activity in the sediments.

According to the relative scientific literature, the anthropogenic activities in Bourgas Gulf have caused petroleum pollution and accumulation of resistant to biodegradation high molecule hydrocarbons on sea bottom. This test reveals the level of petroleum pollution and it is expected to serve as a useful tool for the interpretation of bioassay data. Hydrocarbons in sediments are determined gravimetrically by threefold extraction of 5 grams of sediment sample with 15 ml chloroform for 30 minutes each. The extracts were collected and evaporated with the use of vacuum evaporator at 160 rpm and 400C. The weight of the residue was calculated as milligrams of total hydrocarbons per gram dry sediment.

According to relative studies [6] total hydrocarbons content in sediments more than 0.5 mg/g is indicative for a polluted sample, while sediments containing less than 0.01 mg/g of total hydrocarbons may be considered as unpolluted. In accordance with this rule, sediments from stations 19, 22, 4, 7, 23, 10 and 12 can be considered as unpolluted; while sediments from stations 8 and 9 – as low polluted and the others – as heavily polluted. Totally, basins "Terminal Container" and "Terminal Oil" are most affected by oil pollution.

It is of outmost importance to note that hydrocarbons extracted from the bottom sediments may be originated from petrogenic and/or biogenic sources and the gravimetric analysis is not that accurate in terms of diversification. The share of hydrocarbons in the total organic matter of Bourgas bay sediments varied between 0 - 8%, except for station 2 that reached 11%.

Moreover, the organic matter in sediments accumulation on sea bottom was an indicator both for the organic matter pollution and also as regards the rate of nutrient turnover. The level of organic matter accumulation and its nature also affected the bacterial activity, namely the phosphatase activity. The data received from the test was used for the calculation of bacterial phosphatase activity per milligram organic matter accumulated in the sea bottom sediments. The organic matter in sediments was determined by Turin's method based on its oxidation by dipotassium dichromate. In most of the sampling stations, the bottom of the Bourgas bay was muddy (except stations 19 and 21 that it was sandy) rich in organic matter. The concentration of bottom organic matter varied from 28 mg/g (station 20) to 372 mg/g dry wt sediment (station 13) and the most abundant of organic matter were the sediments of basin at Container terminal or terminal "West".

In addition, the high organic matter concentration in the sediments of Container terminal was another indicator of the Vaya lake adverse effect on water and sediment quality in the basin.

The accumulation of high concentrations of organic matter on the sea bottom, especially on that of "Terminal Container" was a result of the low self-purification capacity of the Bourgas Bay.

Furthermore, the testing phosphatase activity of sediment bacterial communities was chosen as a biomonitor taking into account the importance of organic matter degradation and the cleavage of the orthophosphate group from organic phosphate compounds. Phosphorus is the growth limiting factor for phototrophic organisms in the sea and its supply depends largely on the regeneration of the phosphate from organic matter accumulated on the sea bottom. The regeneration process was carried out by exoenzymes called phosphatases. This test indicates whether sediment bacterial communities in the different points of sampling are intoxicated and also the levels of intoxication. In phosphatase assay, the phosphate group of p-Nitrophenylphosphate (p-NPP) is hydrolytically cleaved by sediment bacteria and the products of the cleavage are orthophosphate and p-Nitrophenol (p-NP). The color compound can be spectrophotometrically measured quantitatively. The routine assessment of sediment phosphatase activity follows a standard format, measuring only alkaline phosphatase concerning the values of environmental pH. In 15 ml centrifuge tube 1g sediment, 4 ml of 1M Trishydrochloride buffer (pH 9.0) and 1 ml 0.2M p-NPP (Sigma) were added. Samples were immediately mixed for 2-3 s in a Vortex mixer and incubated in dark at 220C for 2 hours. The reaction was stopped and color was developed at the end of the incubation by adding 1 ml 0.5M CaCl2 and 4 ml 0.5M NaOH to the sample. The sample got centrifuged at 3 000 rpm for 10 min to pellet the sediment and supernatants were measured spectrophotometrically (CECIL 3021) at 420 nm. Absorbance readings were converted to μg of p-NP per gram dry sediment/milligram dry dead organic matter per hour by comparison to a p-NP standard curve. Spectrophotometric blank sample getsprepared replacing the p-NPP from the reaction mixture with 1ml 0.2M Tris buffer (pH 9.0). Bacterial phosphatase activities (μg/mg sediment organic matter/h) in the basins of the Bourgas port were relatively stable and equal to that of the referent stations (outside of the port waters – stations 21 and 22) on average, except that of the terminal 2A and the Container terminal where the rate of reduction was around 40%. The stability in bacterial phosphatase activities across the sea bottom is a result of the persistence and the long lasting remaining time of pollution, as well as the capacity of bacterial communities to adapt to the new created environment changing their structure and composition. The sediment bacterial communities from basins of the Container terminal and the terminal 2A could not overcome the anthropogenic stress resulting in inhibited phosphatase activities and therefore reduced share in nutrients' cycling.

The basin of the Container terminal was highly eutrophic and unfavorable for bacterial growth while the values of the environmental factors measured in the basin of the terminal 2A were more favorable. The low bacterial phosphatase activity in the terminal 2A basin may be a result of the toxicity of Zn whose concentration is the highest among the basin's sediments measured or with grater probability - the impact of unstudied factor/factors (environmental and/or anthropogenic) in the survey.

The ecological state of the sediment bacterial communities (express by bacterial phosphatase activity) range from "Moderate" at basins of the Container terminal and the terminal 2A to "Good" at the basins of the terminals "East", "Ro-Ro" and "Oil". The eutrophication and pollution of Bourgas bay started with the beginning of the industrialization of the region (1965-1970) and continued till the 1990 when a new environmental legislation limited the rate of anthropogenic impact of human activities on the Bay. Consequently, great improvements in terms of sustainability were succeed for the marine communities for many years. Moreover, biodiversity issues were also identified in the region as sensitive species reduced their number or completely vanished while the others flourished and proliferated. These changes made marine communities more flexible and well adapted to the new environment created as a result of intense human activities in the port area.

Added to that, energy dispersive X-ray fluorescent method, is one of the most popular methods for determination of element concentrations in environmental samples, especially marine sediments. This is because of the simultaneously determination of many elements (32), relatively simple sample preparation procedure and information from large amount of the sample. Detection limits for the different elements are between 1 and 10 μg/g, depending on the matrix and Z of the element. Relative uncertainty between 1 and 10% are typical for trace element analysis.

The obtained results revealed that there was no significant deviation, except for high concentrations of Cu, Zn and Pb in samples 5, 11 and 14.

Natural background levels of heavy metals existed in the majority of the sediments due to the mineral weathering and the natural soil erosion. Human activities lead to pollution, acceleration and the accumulation- increase of the background level of heavy metals to levels that have already caused detrimental effects on the natural environment. Living organisms require trace amounts of some heavy metals, including cobalt, copper, iron, manganese, molybdenum, vanadium, strontium, and zinc. Excessive levels of the essential metals, however, can be detrimental to the other organisms. Non-essential heavy metals of particular concern to organisms were cadmium, chromium, mercury, lead, arsenic, and antimony. Bourgas bay sediments were much more loaded with heavy metals than the sea water and with an important concentration of copper (Cu), zinc (Zn), manganese (MN), strontium (Sr) and lead (Pb). The concentrations of Cu in the sediments of the Bourgas bay basins exceed from 7 to 26 times compared with the control station (32 ppm). Not to mention that the most polluted station was station 11 located in the Ro-Ro terminal.

III. Discussion and Recomendations

After the Bourgas port expansion the newly built terminals "West" and "2A" enter the sea and together with the new breakwater, they form three semi open to the sea internal basins, where the berths are situated. Due to its architecture, the waters of the small Bourgas bay are in a permanent interaction due to the coastal circulation currents with the wastewater treatment plant and the waste water from industrial zones discharge, and also with the port aquatory waters.

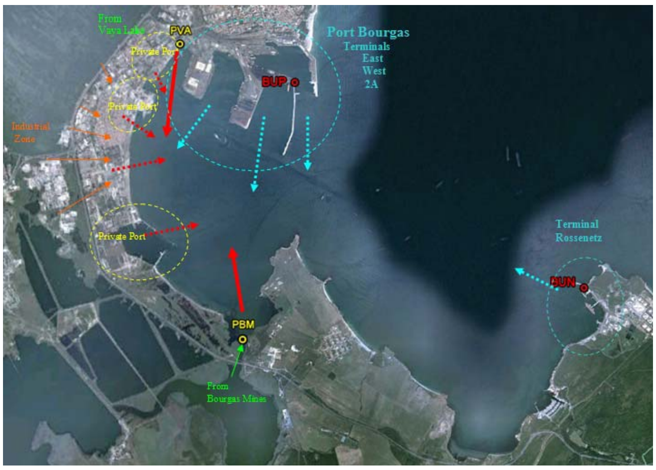

Fig.5. Map of existing pollution sources

These new circumstances established in Bourgas Port, stressed the need for the investigation, design and operation of the port monitoring system. According to the Pilot monitoring plan one of the primary tasks is the determination of the most polluted zones in the port aquatory, including the ones potentially endangered by oil and other hazardous liquid spills from ships. In parallel, along with the assessment of the port water and the sediment pollution it is important to identify the dominant pollution source as a consequence of human activity and the pressure arising from the overpopulation of Bourgas city the growth of industry and port activities (Fig.5). According to the results of the performed monitoring procedure, it could be concluded that there is no specific contamination in port waters of Bourgas Port; however, intense human activity led to significant pollution levels of the coastal waters by different types of contaminants, mainly by petroleum hydrocarbons, organic pollutants and heavy metals. Not to mention that Bourgas port waters are subject to intensive human impacts because of their close proximity to the city and the industrial zones along the coast and therefore it is crucial to establish and operate an integrated Monitoring System in order to deal with environmental vulnerability and assure sustainability for the broader area providing the citizens a quality of life.

Indeed, as environmental awareness constitutes a critical issue also on a social basis, it is of outmost importance for stakeholders to follow port operations and development under compliance with environmental sustainability schemes. This in turn means that monitoring systems are adopted for the acquisition of scientific evidence and quantifiable measures in order to provide port managers with various important information and enable them to detect environmental impacts and causes of certain charges, information on environmental indicators and many others [8]. Through the utilization of real time and historical data specific environmental indicators can be defined as indicative for the designation of biological, physical, chemical, environmental, economic or social system performance [9]; aiming at the improvement of the natural environment in port and the surrounding coastal areas. In addition, the European Marine Strategy Framework Directive 2008/56/EC has adopted ecosystem-based management as a key priority of its objectives aiming to apply an ecosystem-based approach to the management of human activities in order to reach a Good Environmental Status (GES) by 2020 [10]. In these grounds, the European Commission (EC) has defined eleven high-level qualitative descriptors of GES, while the Directive is now serving as one of the most significant policy drivers for marine monitoring and assessment in all member countries [11].

Considering the EC requirements, the necessity of acquiring and utilizing marine monitoring systems is listed on top priorities for port authorities, as these systems can be a component for capacity building in order to achieve Good Environmental Status in port and their surrounding areas. In fact, the examination analysis and integration of historical and real time data are the pillars for the design of a certain profile for the area of interest; offering decision makers eligible tools for safeguarding operations in case of disaster risk management.

Especially, as regards the last scenario of natural disasters such as floods, or marine accidents such as oil spills, the utilization of monitoring systems is expected to assist emergency plans and actions for the prevention of harmful impacts that can lead to serious environmental, financial and social disasters. Safety issues, along with sustainability goals and efficient environmental management of port activities can be achieved by the comprehensive understanding of environmental conditions, features and parameters, and also the climate change impacts on marine environments. Therefore, strategic planning should undoubtedly be a part of effective integrated environmental management of ports and coastal areas in order to deal with natural and man - made hazards.

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