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"Feasibility study – Port of Tripoli"

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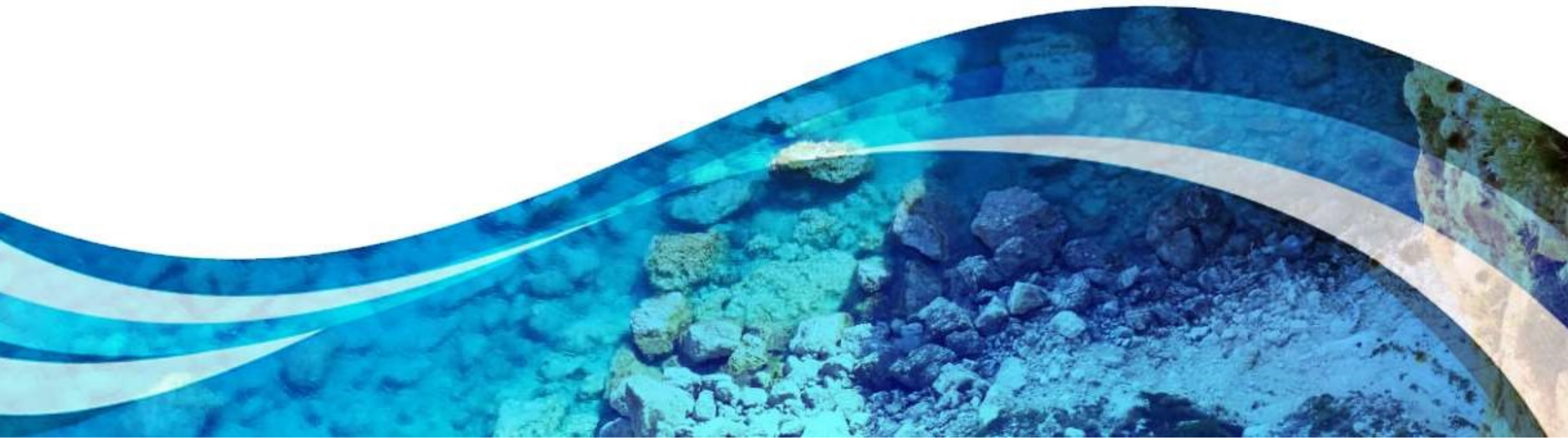

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CONTENTS

EXECUTIVE SUMMARY

ECOMEDPORT start-up action promotes the adoption of an **innovative and sustainable technological solution** demonstrated in Italy in two EU projects: the LIFE MARINAPLAN PLUS and the InterregMed CO-EVOLVE, that is part of the UfM labelled "MedCoast4BG" framework project downstream to the Bologna Charter initiative implementation. The technological solution, which is based on the "*ejector plant*" technology, is able to achieve a **more efficient and less impacting management of sediments** in water bodies, with the final results of ensuring a safe navigability. In particular, ECOMEDPORT opened **two disseminating channels among ports' stakeholders in Tunisia and Lebanon** through the involvement of local partners and invited experts. The **execution of three main events**, one in Italy in September 2019 (including demo sites visit) plus two webinars focused on local Tunisian and Lebanese stakeholders to evaluate the exploitation potential of the ejectors' plant technology. The two local conferences were organized as on-line events due to Covid-19 pandemic limitations. The **outcomes of ECOMEDPORT start-up action** are **two feasibility studies**, which will serve as techno-economic tools for the follow-up of the project.

1. INTRODUCTION TO THE EJECTORS PLANT TECHNOLOGY

More than 90% of global trade is carried by waterborne transport, constituting by far the most important means of transport of goods. Therefore, global trade is critically dependent on adequate ports and waterways navigation status (**navigability**), since a limited water depth reduces vessel and boat draught, which is strongly related with load capacity, thus impacting on goods and people traffic volumes and related costs. Preservation of a good port navigability is a challenging issue, since port access and waterways are often hampered, as the vast majority of tens of 1000s of ports worldwide suffer from **sedimentation**. Traditionally, the sediment that causes the problem of siltation is excavated, removed and relocated: this operation is defined as "**maintenance dredging**". Millions of cubic meters of such sediment are dredged annually from harbour approaches, fairways and basins to safeguard obstructed navigation. Dredged volumes are expected to increase due to continued economic growth and increases in vessel and boat draught. Maintenance dredging is thus necessary at both large commercial and small craft harbours.

Maintenance dredging also has **considerable environmental impacts**, since dredging operations can: i) destroy or greatly modify underwater habitat, ii) disturb contaminants already present in the water bed, thus increasing the Suspended Solid Concentration (SSC) in the water column with negative effects on the ecosystem, iii) impact locally on greenhouse gas (GHG), pollutants and noise emissions, iv) generate a waste to be disposed, i.e. the dredged material. There is an increasing expectation for infrastructure projects to add value beyond the economic dimension since **sustainability** issues are of growing importance. In fact, ports and governmental organisations are demanding more sustainable products and services, and the main leverage to achieve this objective is through more restrictive legislation. As a result, maintenance dredging operations are often becoming difficult to plan, too expensive and sometimes not allowed by regulations.

Compared to traditional dredging, the **ejectors plant** is more cost-efficient, reduces port downtime/access losses, is environmentally superiorsafer, and it enables zero-emission sediment management.

The "ejector plant" is mainly executed through the assembling of a **pumping-filtering station** that feeds with pressurized water one or more ejectors through a system of pipelines. Each ejector has one **water feeding line** and one **discharge line** that transports a **water-sediment slurry**. The ejectors plant has been developed and designed to **continuously shape the water bed** and to **keep it at a certain depth** over time with the following targets: i) **no-moving mechanical-electrical parts** in the ejector, ii) **minimize the environmental impact**, iii) **no water turbidity**, iv) **not** being **an obstacle for navigation** while in operation, and v) being **easy to integrate** within the water body architecture and landscape. The ejector works with the sediment that naturally comes to a certain area, and so **it does not remove the sediment** from that area (no dredging!).

The working principle of the ejector is based on the **combined effect of two different nozzles' jets** (Figure 1): the radial nozzles create a suspended mixture of water and sediment, while the central nozzle sucks up through the Venturi effect the water-sediment mixture, and collects it in a discharge pipeline.

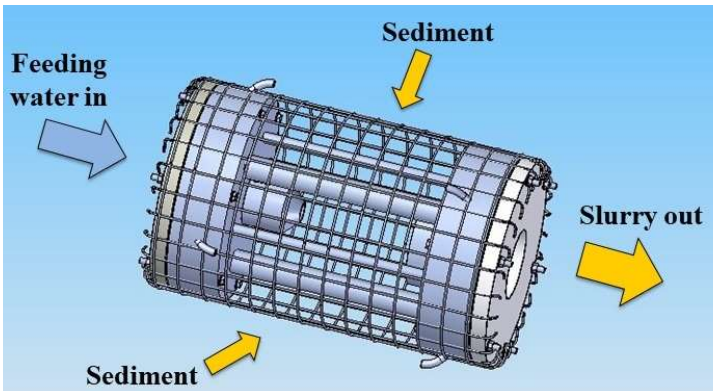

Figure 1. 3D render of the ejector.

The ejector **efficacy** is influenced by **sediment characteristics** (the lower the friction angle of the sediment the higher the area of influence of each ejector), while the ejector **efficiency** by the **length of the discharge pipeline** (the higher the length, the higher the energy needed to operate). Operation is not influenced by water depth. Therefore, the design of the ejectors plant is **tailored on customer needs**.

The working principle makes the "*ejectors plant*" a unique solution with **no comparing competitors on the market**: i) it ensures, with 100% accuracy, the sediment pick-up, depending on the position of each ejector; ii) the sediment, sucked by the ejector, is conveyed to a delivery point chosen by the designer; iii) it allows continuous control of the discharge dilution and solid speed, depending on the sediment load. The ejectors plant guarantees 24/7 navigability, zero environmental impact in the water body, near-zero on shore.

Starting from 2005, the technology has been already tested and validated in Italy in four different locations. In the **LIFE MARINAPLAN PLUS project** (LIFE15 ENV/IT/000391, 2016-2020) the implementation of the first industrial demonstrative plant has been co-financed. The demo plant was operated by TREVI for 15 months at the entrance of Cervia harbour (Italy) and the navigability was guaranteed for the whole period with a near-zero impact on marine environment. Therefore, **the technology has already achieved TRL-7**.

2. PORT OF TRIPOLI DESCRIPTION

The city of Tripoli, 85 km north of Beirut (the capital), represents with its international transit port the commercial and industrial center of Northern Lebanon and the second city in Lebanon after Beirut in term of density of population and anthropogenic activities. In particular, for the past several hundred years, Tripoli City (North Lebanon) has been serving as important seaport for shipping, transportation and fishery activities.

Figure 2. Lebanon map.

Port of Tripoli located in the Northern area of Tripoli city (34°27’19’’N, 35°49’14’’E) is the second port in Lebanon after the Port of Beirut. It is among the most important ports on the eastern basin of the Mediterranean Sea because it is a link between the East and the West. The port of Tripoli was able to quickly fill the gap caused by the recent Port of Beirut Blast on August 4th, 2020 that almost destroyed the entire Beirut Port and crippled all the logistics associated with its economic activities. Tripoli Harbor expansions and floor deepening that took place during the second decade of the twentieth millennium has paid off. As many activities were transferred to Tripoli Port and its adjacent area, the port of Tripoli plays now an important role at the national level. The port covers an area of approximately 3 million m^2, with a water area of 1,500,000 m^2, and a land area that consists of 950,000 m^2, and a 550,000 m^2 of dump area destined as a future free economic zone.

Figure 3. Aerial view of Tripoli port.

Indeed, Tripoli Port is divided into two ports; the first one for the **harbour activities** and the second for **fishery activities.** The harbour has 2 semi-enclosed basins due to the presence of two breakwaters: 1900 m and 1300 m long respectively, and 1000 m with **depths varying from 8 to 10 m for operated old quay,** and 1200 m long with **15.2 m depth for the new quay**. The old quay receives general cargos and dry bulk solids such as steel, wood, sugar, various beans, iron scrap, vehicles, construction materials, fertilizers and coal. The new quay is used as a multi-purpose terminal; 400 m long dedicated to the handling of container ships and the other 200 m are specialized in the service of big dry bulk ships. Actually, the harbour receives about **450 ships per year** with an average of **37 per month** [1,2].

The **Fishermen Syndicate of the North** is the reference organization for fishermen and the head is also chief of the Fishing cooperative. The Syndicate gathers six seaports of the north of Lebanon and few villages that carry out their activities at the sea, mooring the boats in small rivers. **Tripoli Fishermen Cooperative gathers 404 boats** (2-3 fishermen per boat). The Cooperative i) manages, in association with the Syndicate, a gasoline selling point at the port, and ii) redistributes funding coming from donors such as NGOs, International Organizations (FAO and other UN agencies) occasionally involved in **programs/projects for the development of the sector**. In Tripoli, there are several selling points located at the city souq, mainly dealing with imported fish. In addition, there are two other selling points located at the port, and obliged by the local institutions (Syndicates and Cooperative) to sell only local fishes [3].

Figure 4. Picture of the commercial Tripoli harbour.

Figure 5. Picture of El Mina fishery port.

3. APPLICATION OF THE EJECTORS PLANT TECHNOLOGY IN THE PORT OF TRIPOLI

3.1 Assessment of sedimentation at Tripoli port

The coastline along Tripoli is affected first by the shadow of the city headland to its south, where the seaport jetty lies. That is where most of the winds and resultant currents blow, i.e. south westerly and westerly, hence **the wave energy regime is normally not high**. The **tidal cycle is minimal** and does not exceed 30-40 cm in general, while **longshore currents inclined or sub-parallel to the shoreline are important** in terms of variation in temperature and salinity. A second effect on the area is at the **Abou Ali river mouth sediments' loads**, bringing solid and liquid wastes [4]. In particular, Abu Ali river's annual flowrate is about 262 Mm^3/year, 2-7 m^3/s in dry season (Jul to Sep) [5], which means a mean instantaneous yearly flowrate of the river of 8.5 m^3/s and a maximum instantaneous flowrate estimated at 15 m^3/s.

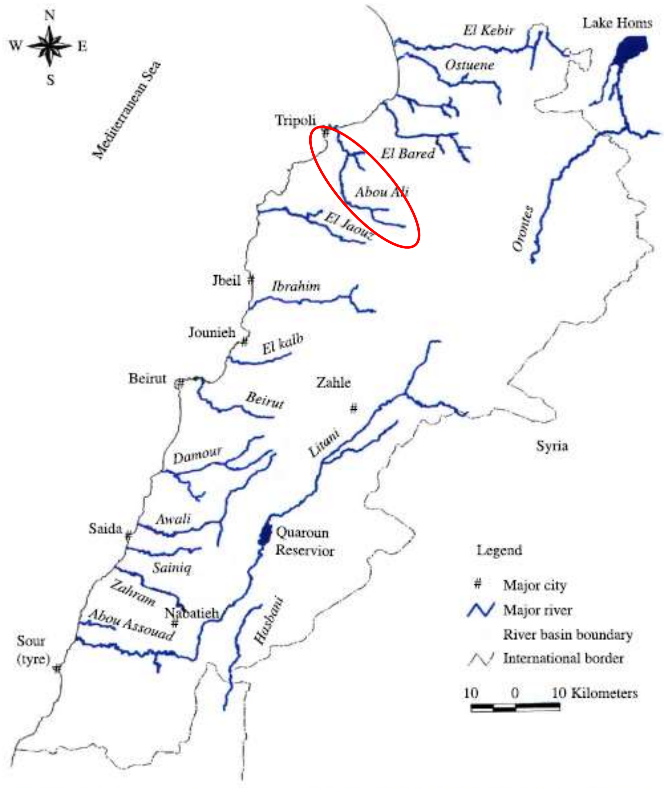

Figure 1 | Map of Lebanon showing major rivers. Reproduced from El-Fadel & Zeinati 2000 ©. Also published in El-Fadel *et al.* 2000 and El-Fadel *et al.* 2001.

Figure 6. Abou Ali River.

The sediment types within the **old basin** are consisted of approximately **7 to 10 m thick layer of clayey sand to sandy clay** with gravel and pebbles, sometimes cemented (conglomeratic). For the **new basin,** sediments are consisted of dark, greenish, grey, stiff to very stiff calcareous **silty clay to clayey silt** (marl), and traces of organic materials and peat were identified. Along the principal breakwater, an approximately 5 m thick layer of calcareous silty sand to clayey sand with gravel and pebbles was found, sometimes cemented (conglomeratic) and underlying an approximately 5 m thick layer of soft to medium stiff brown sandy to silty clay with gravel. **The clay content in Tripoli harbour sediments is in the order of or greater than 30%** [2].

The main impact on **port sedimentation** should be given by silt-clay sediments moving alongshore and by sediments discharged by the Abu Ali river immediately North to the port entrance, and by other rivers in the northern side of the port area. Authors' hypothesis is that in some weather conditions (i.e. wind from East or South-East direction, plus growing tide, plus river sediments transport due to rain or others), the suspended silt and clay sediments move to the **port entrance** and **inside the port**, and then settle (usually near to the quay, docks, etc…), but especially on the bottom of the newly excavated 13.5 m deep area on the container terminal.

Figure 7. Sedimentation sources in the Port of Tripoli.

3.2 Technical analysis

3.2.1 Commercial harbour docks' protection against sedimentation

What usually happens in commercial harbours is that in the evolution basin, a higher depth can be found, while near the quays/docks the sediment re-suspended and moved by ships' propellers operation settles down. This kind of phenomena has been observed, for example, also in the commercial Port of Ravenna (Italy), where some field tests have been already carried out with the ejectors plant technology. A **modular system with up to 5 ejectors** can be designed to protect a specific dock from sedimentation. In that case, **the sediment can be redirected to the evolution basin**.

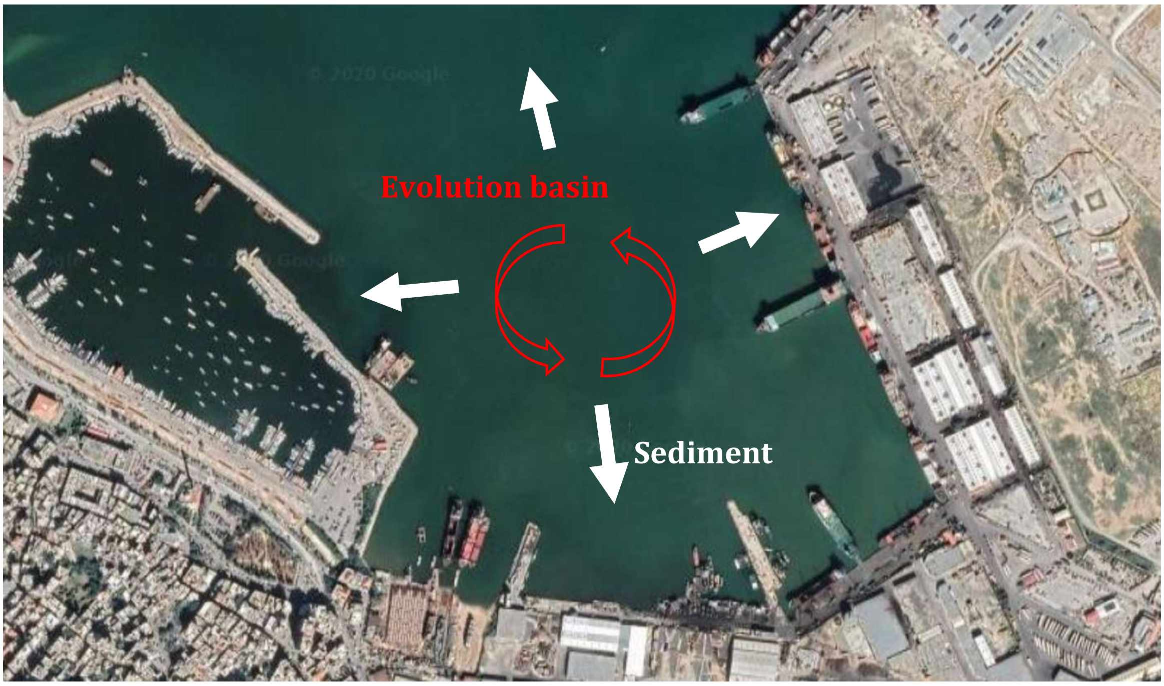

Figure 8. Sediment resuspension phenomenon produced by ships' propellers.

Figure 9 shows a preliminary sketch of the P&ID of a 5 ejectors module: the main element is a centrifugal pump, controlled by inverter which feeds with pressurized water the 5 ejectors via a manifold. On the manifold the pressure is monitored, as well as the water flowrate in each water feeding pipeline for the ejectors. The length of the water feeding pipeline can be in the range of 15-30 meters, while the **discharge pipeline is defined in 120 meters**. Based on sediment characteristics, it is assumed that **5 ejectors can cover a dock length of about 50 meters**.

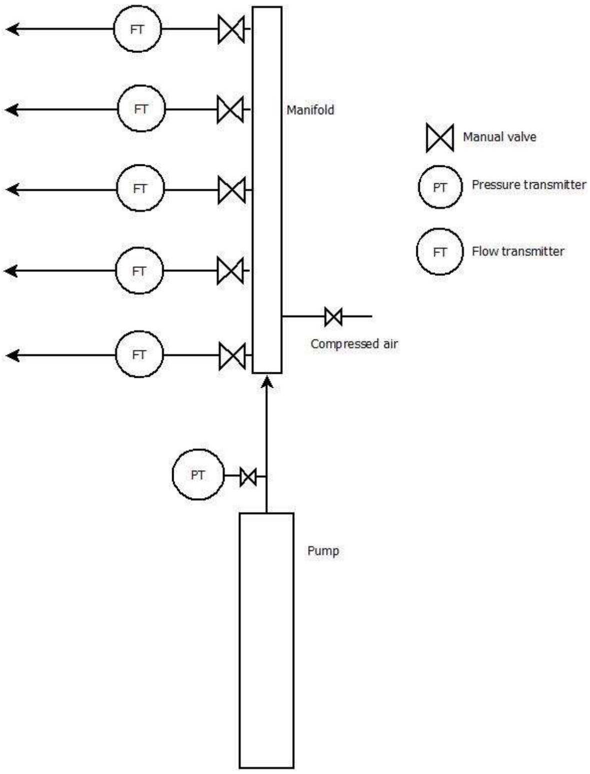

Figure 9. P&ID of the 5 ejectors plant designed for the commercial harbour.

Figure 10. Example of application of a 5 ejectors plant in the commercial harbour.

3.2.2 Fishery port entrance

Fishery port entrance is located in the southern area of the port. The aerial view (Figure 11) clearly shows how water depth is not constant in the entrance/exit channel. In this area sedimentation is probably mainly due to marine/wind currents coming from north and north-west directions. The area is partially protected by the Baqar Island.

Figure 11. Fishery port entrance.

A **plant with 10 ejectors** should be enough to **cover a length of 100 meters** in the area that seems more affected by sedimentation. The plant can be assembled as two modules of 5 ejectors (see P&ID of Figure 9 as an example of one module). Pumping devices may be installed on Baqar Island, while the discharge pipelines may be directed to Tripoli beach, thus reducing **discharge pipelines' length to 30-40 meters**.

Figure 12. Example of a 10 ejectors plant installation at the fishery port entrance.

3.3 Economic analysis

The following economic analysis is based on the experience of Trevi in the execution of existing demo plants in Cattolica and Cervia (Italy). The costs may be different if the use of local manpower (in particular, divers) would occur. The **cost of electricity** is currently considered equal to **0.10 €/kWh**. Energy cost could be strongly reduced if ejectors plants installation would be coupled with a renewable source (i.e. solar or wind). All estimates have been based on the official local currency rates prior to the recent hyperinflation in Lebanon. While imported goods cost may remain unchanged, local expenditures may have dropped which makes the project more appealing as compared to current applied methods.

3.3.1 Commercial harbour docks protection against sedimentation

The **investment cost** of a 5 ejectors' module is estimated in **300.000 €**, including design, installation and commissioning. Costs that are excluded from this estimation: the implementation of civil works on-shore and off-shore, if needed; increasing power availability at the docks, if needed; permit/authorization costs.

The operation costs are associated with electricity consumption. The mean power consumption of the plant is estimated in the 30 kW range, which represents an energy consumption per year of about 255,000 kWh. Therefore, the estimated **operation cost** is **25,500 € per year**.

The **maintenance costs** can be estimated at about 3,000 € per year per installed ejector, which means **15,000 € per year**.

3.3.2 Fishery port entrance

The **investment cost** of a 10 ejectors plant is estimated at **800.000 €**, including design, installation, and commissioning. Costs excluded from this estimation are: the execution of civil works on-shore and off-shore, if needed; the increase of power availability at the docks, if needed; and permit/authorization costs.

The operation costs are associated with electricity consumption. The mean power consumption of the plant is estimated at 40 kW, which means an energy consumption per year of about 340,000 kWh. Therefore, the estimated **operation cost** is **34,000 € per year**.

The **maintenance costs** can be estimated at about 3,000 € per year per installed ejector, which means **30,000 € per year**.

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