EVALUATING SEA WATER QUALITY IN THE COASTAL ZONE OF NORTH LEBANON USING TELEMAC-2D^TM^

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ABSTRACT

The coastal zones of the Mediterranean are undergoing rapid development with growing and conflicting demands on the natural resources. Coastal zones are often subjected to irreversible land degradation and environmental deterioration. Lebanon is located in the eastern part of the Mediterranean basin and the integrated management of the environment in the Lebanese coastal zone must be given concern. Most of the successful decisions addressing the environment protection or the elaboration of preventive measures in the coastal zone. These decisions depend on the availability of efficient simulation tools. The existence of these tools can help protecting the environment and establishing the ground for sustainable natural resources in the coastal zones. In this paper, a simulation tool called Telemac-2D^TM^ software was used to simulate the business as usual, pessimistic, and optimistic status of the sea water quality in the coastal zone of Tripoli (North Lebanon). The coastal zone is affected by the effluents of solid and liquid wastes from Abou-Ali river. The different quality states of the coastal zone represent the normal, high, and low flow of the effluents (plume pollutants) from Abou-Ali river. In addition, it represents the variation of different factors such as wind and sea currents speed and direction. This simulation will help the decision makers to implement pre-cautious measures before a disaster takes place by assessing the quality of the sea water near the coastal zones.

Keywords: simulation, sea current, wind, river, water quality, coastal zone

INTRODUCTION

Lebanon has few kilometers (about 220 km) of shoreline lying along the northern segment of the eastern Mediterranean. Tripoli is the second largest city in Lebanon, with a population of about 400000 people. Like other coastal stretches, urbanization and development projects are rapidly overtaking the area. This is occurring at the expense of the coastline on one hand and agricultural plantations through which Abou-Ali river flows on the other hand.

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 long shore currents inclined or sub-parallel to the shoreline are important in terms of the variation in temperature and salinity. A second effect on the area is at the river mouth sediments loads, solid and liquid wastes. There are several sources of pollution such as the slums in the absence of proper infrastructure. This is in addition to the poorly implemented housing policies, areas outside proper legislation and the lack of municipal human and financial resources. The pollution is redistributed by the waves building sandy beaches mixed with debris. The third effect is the interference of the local authorities which, in the past, used the river mouth as an open solid waste dump of the city. Recently, official authorities modified the spot into a more controlled land fill operation where soil is spread in layers over the waste and this is repeated with compaction.

The Abou-Ali river, which is the resultant confluence of three major tributaries, about 8 to 10 km east of Tripoli inland, serves as the place of outfall of untreated multi-pollution sources. This includes agro-chemicals, sewage, wastewater, some industries effluents and a mixture of solid wastes, especially from the city, through which the river passes for less than 2 km (Massoud *et al.*, 2006a; Massoud *et al.*, 2006b).

The river tributaries connect in the open plateau a short distance east of Tripoli, with annual flow of about 262 Mm^3 (SOER, 2001). The bottle-neck situation it has just at the entrance of the city, often leads to flooding. A prominent flood event occurred a couple of decades ago (before the concrete lining) with resultant huge damages to property, loss of lives and a deposition of about 200000 m^3 of sediments in one day creating a delta. The authorities thus converted the passage where the river passes in the city into concrete lining.

With a population density of $15000/km^2$, it is obvious that Tripoli's environmental living conditions are not that positive because of the absence of land-use planning and adequate infrastructure. This explains the environmental deterioration of natural resources including the area covering the river mouth and adjacent beach. The touristic and industrial exploitation of the beach without proper implementation of existing laws is making it non-available to the public and deteriorating at a high rate. Indeed, elsewhere in the surrounding the pattern of change in land use has been drastic with an increase in losses of prime productive land (Darwish *et al.*, 2004). So long as the problems of waste water network and solid waste management system are not properly treated, pollution and health problems, both from the river and sea, will remain.

The goal of this paper is to emphasize how the plume pollutants flow from Abou-Ali river deteriorates the coastal area and how the degree of pollutants concentrations can be identified using simulation and modeling software called Telemac-2D (Cooper, 1995; E.D.F.-D.E.R., 2002a; 2002b).

MATERIALS AND METHODS

A hydrodynamic model is needed to estimate the current speed and direction in the study area (Figure 1) and for the simulation purpose. In order to build this model, several spatial and non-spatial data are obtained from different sources. One of the spatial data is the bathymetry (10 meter interval) (ECODIT – IAURIF, 1997) for building the mesh necessary for the hydrodynamic model. Another is the coastline obtained from the topographic map with a scale of 1: 50000 meter (DGLA, 1965) to define the limit of the mesh. The small details of the coastline are not considered here because a general conclusion of the fate of all type of the river's effluents is the goal. Otherwise a satellite image with high resolution must be used.

Finally, wind direction survey data (MTT-SM, 1982; DGAC, 2006) and flow of Abou-Ali river (SOER, 2001) are used in the simulation

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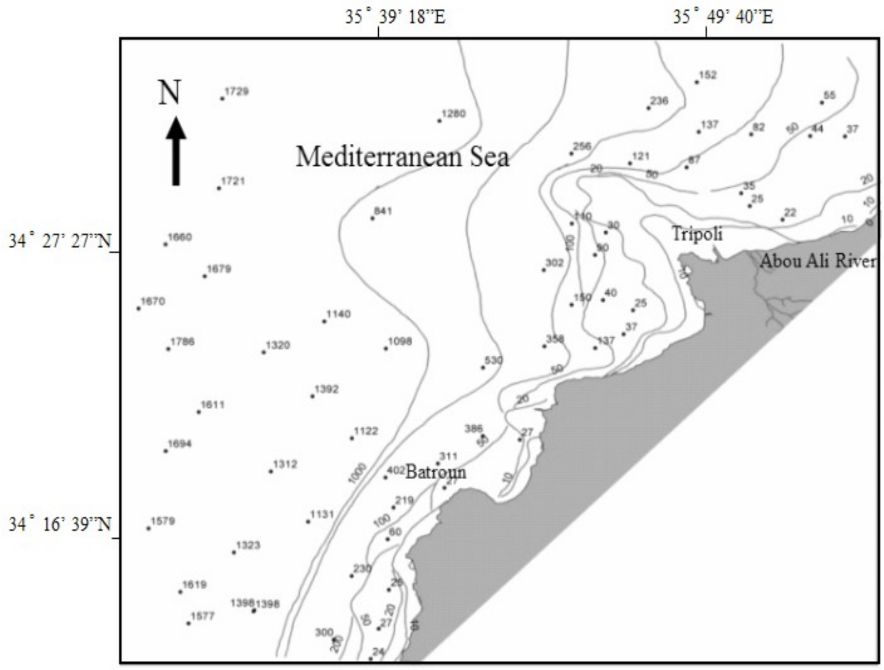

Figure 1. Gulf of Tripoli and Abou-Ali River.

In addition to the above data, the Telemac-2D software (created by Electricité de France (EDF) and distributed by SOGREAH) requires a detailed description of the river. For this reason, a cross section along the estuary describing the river was created (Figure 2) with the following characteristics:

- River estuary width = 12 m
- Average depth at the mid-point = 1m
- Cross-section area = 7.70 m^2
- Depth at the south west (SW) side = 1.25 m
- Depth at the north east (NE) side = 0.75 m

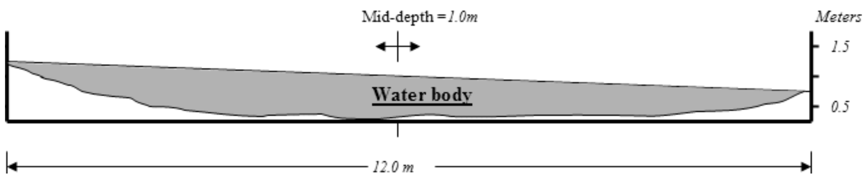

Figure 2. Cross-section along the estuary of Abou-Ali river.

At the estuary of Abou-Ali river the depth of water reaches 2.5 m at a distance of about 400 m. The bathymetric gradient at the estuary of Abou-Ali river is around 9.25m/km, which is relatively gentle. This would be decreased at a range in the sea and reaches around 6.25m/km. To build the hydrodynamic model, the influence of wind on the water surface is considered. The model domain is limited by two types of boundary conditions (solid or water). To build this model for the area of study, Matisse is one of many modules in Telemac-2D software. Matisse role is to construct the mesh (grid) which is the backbone of the simulation model. A polygon mesh is a collection of vertices and edges that defines the shape of a surface being modeled (Tobler & Maierhofer, 2006).

Before constructing the mesh of the studied area, the nodes in the mesh were made denser in the area of concern near the river. This is done in order to attain more accuracy in computation. The following are the properties of the mesh:

1. Minimum depth is -1meter and maximum depth is -1679 meters.
2. Number of nodes is 3059 and the number of elements is 5867.

The duration of the simulation in Telemac-2D is 259200 seconds corresponding to 72 hours and the graphic printout is equal to 600 seconds.

Wind direction and intensity at different time are shown in Figure 3. At 6 hours run the wind was in the direction north-east, in the direction north-south after one day of run and in the direction of north-east again after three days of run. The direction and intensity of the wind define currents direction and intensity.

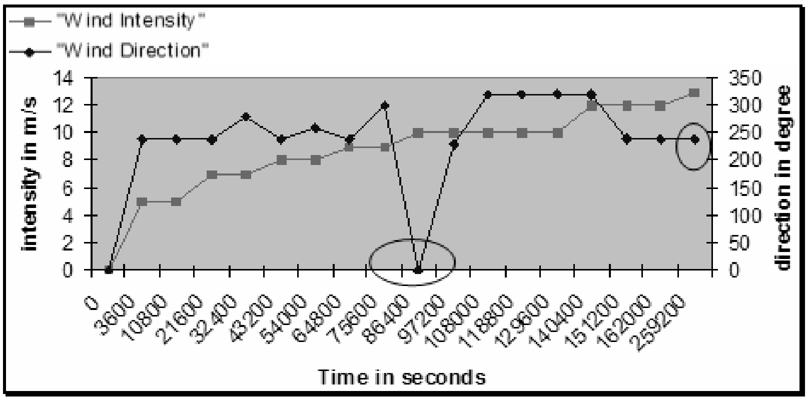

Figure 3. Wind intensity and direction.

To explain how Telemac-2D simulates current direction and intensity with respect to wind, some points are picked at different times (1 day, 3 days) from the chart. Figure 4 shows the sea current intensity and direction after three days simulation period by Telemac-2D. One can notice the abrupt change in wind direction after three days of run and the consequences. This change caused the current speed to slow down and the deviation of the current toward a different direction. Later, the current velocity increased suddenly toward north-east due to wind speed increase and direction change toward north east.

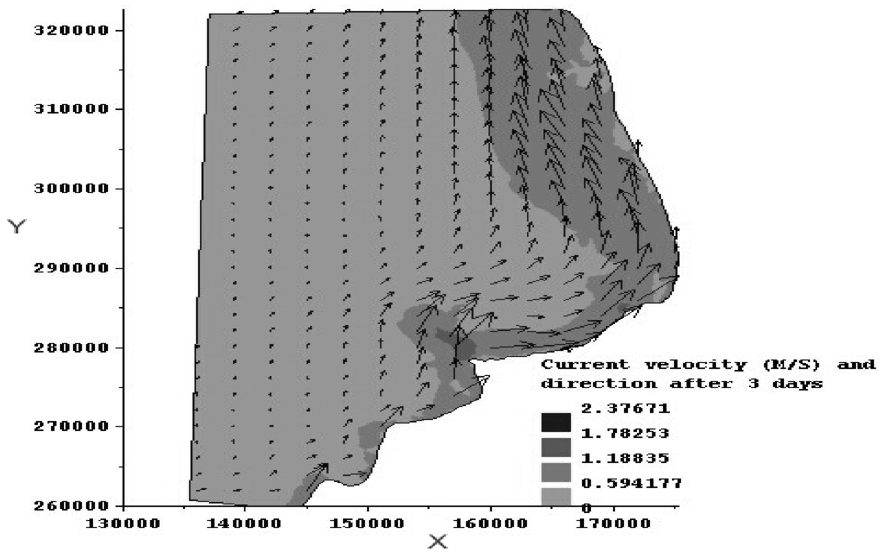

Figure 4. Current intensity and direction after 3 days.

The important factors that influence the hydrodynamics of the area are the wind and the currents resulting from the wind action.

The long-term goal is to understand the disposition of river pollutants on the Lebanese northern coast. Ultimately the aim is to be able to predict the fate of pollutants spilled into one of the Lebanese rivers. Specifically what is wished is to determine how much of the pollutant would outlet the waters near the river outlet and into the sea. The main pollutants source in Abou-Ali river that outlets in the sea near Tripoli city are: 1-the untreated sewage, 2-minor industry effluents and 3- the seasonal waste of the olive oil industry "jift" which build up after olive fruits treatment..

A strongly irregular coastline and non-uniform bottom relief characterizes the coast region. According to the measurements carried out in the sea water of the study area and the surrounding area, the mean current velocity vector is directed along the coast to the north and north east (Dzhioyev & Drozdov, 1977). In order to measure the velocity of the currents, several self-contained buoy stations (ABS) are placed near coastal line of Beirut and Jounieh (see Kibar & Sokolov, 1988 for more details). These buoy stations are placed for several days and are programmed to measure the current speed and other important parameters. According to this data provided by these stations the average speed of the sea current is not greater than 3.3 cm/s.

Wind plays an important role on the speed of the sea currents and in defining the scenarios. Wind speed and direction in December 1997 varies between 15-40 km/h in the direction of north east or north south. The wind has a significant effect on the pollution plume dispersion in the northern part of Lebanon.

By comparing the measurements provided by the ABS stations and Telemac-2D results, one can see slight difference up to specific period of time (Figure 5). This difference was caused by changes in the wind speed during Telemac-2D simulation. The wind speed increase causes magnification of the sea current speed (Cochin *et al*., 2008).

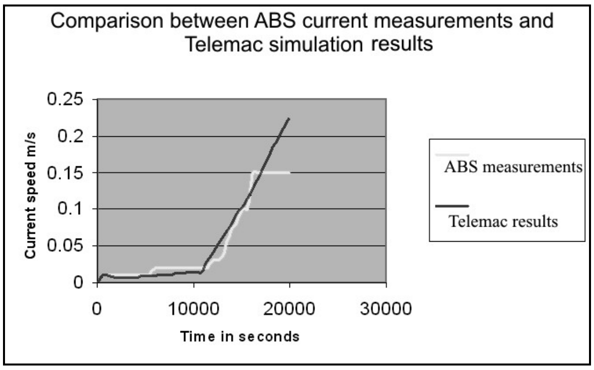

Figure 5. Comparison between the measurements of different ABS stations and the Telemac-2D simulation result.

From the chart one can see that Telemac software provides accurate simulation of the current speed and direction. This is helpful for decision makers to know ahead the possible outcome of any pollutant spill. In addition, the ABS measurement can be simulated using Telemac in case these measurements are not available as seen in the above chart.

RESULTS

The first scenario starts with business as usual case where the average daily spill of sewage is about 0.2 m^3/s. This volume of sewage waste is calculated by taking into account that a person produces an average 150 liter/day of sewage waste (Petroczki, 2006) and that about 150,000 inhabitants are living in Abou-Ali river basin. The solid waste mass is 1.5 g/l and the river discharge is approximately 12 m^3/s. The water treatment station in Tripoli treats about 40000 m^3/day sewage. Telemac-2D was used to simulate this scenario and the simulation provided us with information about how the plume pollutants are transported.

A separate module which uses the simulation results of Telemac-2D provided us with an indicator about the quality of the water in the scenario (Figure 6a). This indicator represents the volume of pollution mass and the concentration of the pollution.

In the second scenario the situation is very pessimistic due to the fact that the season of olive oil production is in the highest pick. Furthermore, huge quantities of “jift” are thrown in the running water. This causes malfunction and deterioration of the treatment station and later decreasing its capacity up to 1000 m^3/day, which causes an increase of solid waste concentration from 1.5 g/l to approximately 4.5 g/l. Telemac-2D simulates the transport of the plume pollutant and helps in producing the quality indicator map (Figure 6b).

In the pessimistic case, all the area around the coast is in bad environmental condition due to the movement of the increased amount of pollutants near the coast.

In the third scenario the situation is very optimistic because there is a decrease in sewage discharge. This is due to improvement in the operation of the treatment plant, to the increase in price of water supply, and to the improvement in service network. In addition, olive oil industry waste “jift” has been treated and recycled, so the pollutant discharge dropped to half. Tripoli water treatment plants are under maintenance contract and upgraded to larger capacity, this brought down the pollutant concentration to less than 0.4 g/l. From the Telemac-2D simulation process one can figure out the transport of the plume pollutant by checking the quality indicator map (Figure 6c). This map indicates that the quality of the water in the coastal area is better.

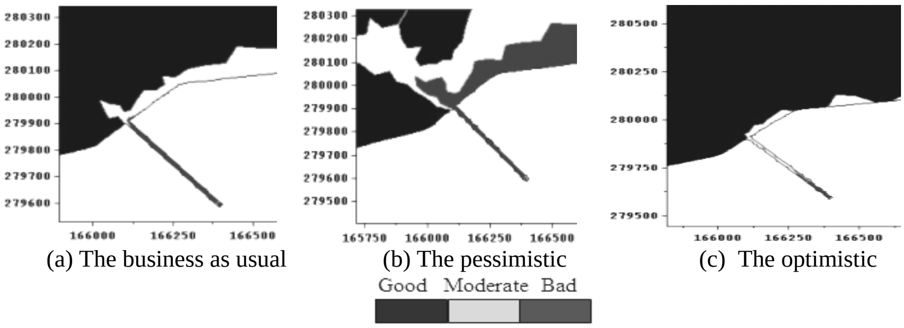

Figure 6. Quality indicator for different scenarios.

The three different scenarios help in predicting ahead the sea water quality status in the coastal zone of Tripoli. The quality is affected by the pollutants plumes which are carried by the Abou-Ali River. The simulation of different scenarios provides knowledge about the quality of the sea water which in turn can help the decision makers. This result could be used to take the precautious measures to avoid the deterioration in the economy due to the increase in the number of tourists and population which in turn leads to the increase of health problem issues which requires more government funding (Given *et al.*, 2006; Prieto *et al.*, 2001).

These precautious measures range between prohibiting the dumping of industrial and urban wastes to the increase in the number of treatment stations. In this research the river was the main cause of the deterioration of the sea water quality, but there could be other sources such as direct flow of sewers in the sea or the oil spill.

CONCLUSION

Management of the coastal areas in the Mediterranean basin is a very complicated issue for the decision makers. The existence of simulation and modeling tools can help in reducing the management burden and in increasing the possibility of taking the right decision. Tripoli is one of the important cities which suffers from the environmental deterioration and therefore depletion of natural resources which leads to retarded economy. Telemac-2D is a simulation and modeling software which is used to help the decision makers in their efforts to improve the economy in the city by reducing the deterioration in the quality of the coastal water. Telemac-2D is used to simulate the quality of the seawater which is affected by the wind activities and local currents. These currents carry the plume pollutants which are originated from plants, urban settlements and agriculture activities, and discharge by Abou-Ali river. The currents are affected by the dominant wind from the north and north-east directions. Three scenarios were taken into consideration, the business as usual status, the pessimistic, and the optimistic case. The concentration of pollutants is lowest in the optimistic and highest in the pessimistic scenario. Although the period is short 3 days the model created by Telemac-2D can help in monitoring the movement of plume of pollutants discharged from river mouth and to plan ahead by creating different scenarios.

In the future this model may be applied to different coastal cities in Lebanon and *in situ* measurements must be carried out to ensure that the model is simulating the reality.

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