

Simulating the Pattern of Pollutant Emission in the Hadish Watercourse

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ABSTRACT

Hadish watercourse located in the in south of Iran, is a seasonal channel of water which crosses through Bandar Abbas to reach to the Persian Gulf. This watercourse is faced with numerous environmental problems in regard with the pollution entrance. Huge amount of the urban and industrial sewages of the city are discharged into this watercourse. In this investigation, considering the discharge of $1.36 \text{ m}^3/\text{s}$ into this watercourse, according to the literatures, the procedure of emission of pollution in the area was modeled. For this purpose Delft3D software has been employed. The model has been calibrated and evaluated considering water level data from Rajaee Port. It was found that, the pollution mainly remains inside the watercourse which is due to the ebb dominance nature of the channel. The results of this research show that the discharging the sewage into this channel endangers not only the western coast of Bandar Abbas, but the health of the citizens.

1. Introduction

Studying the quality of surface waters, such as streams and watercourses is of particular importance. This is specifically more crucial when this waterway crosses through a city. It also requires further attention when sewage and industrial or urban wastewater are released to them. According to Montuelle and Graillot the urban, and industrial developments produce many pollutant emissions, in increasing quantities and of a highly variable nature [1]. The problem will be arise when these materials are discharged to a waterway or a stream inside a city [2].

Hadish watercourse is one such waterway, which crosses across Bandar Abbas city to reach to the Persian Gulf (PG). Bandar Abbas is a coastal city in the south of Iran, and is also the center of Province Hormozgan. Figure 1 shows the location of the city in the province Hormozgan (A), the area considered for the model establishment (B), and the position of Hadish watercourse inside the city (C). This watercourse is also a tidal stream which could be count as complex watercourse that represent a transitional zone between riverine and marine systems [3].

The length of this watercourse is about 3000m., and its width in its mouth is about 60m [4]. The depth of the channel reaches up to 2.5 during flood period, when the channel is filed with Persian Gulf's water [5].

According to literature "if the pollution transport and dissemination mechanism in estuaries or rivers is

specified, planning may be made to reduce the effects of pollution on public health" [6]. Generally, when a sewage pollution is released into water, it quickly spreads and is transferred by water flow owing to molecular motions, turbulence, and non-uniformity of velocity in flow section [7].

The health of Hadish watercourse nowadays is at risk. Vast amount of urban and industrial sewages from the city itself and from the neighboring area are discharged to the channel. The aim of this study is to find out the destination of the release pollutant in this channel, and the role of this sever channel for polluting PG. The pattern of the pollution during the tidal cycle has been investigated using Delft3D software.

2. Materials and Methods

2.1. Model establishment

The two dimensional version of Delft3D software, developed by Delft Hydraulic in Netherland, has been used for this investigation. The Flow Module in combination with Water Quality module of the model were considered to use [8]. The area considered for the modeling has been chose far out of the watercourse into the PG, far enough from the mouth, to prevent flow disturbances inside the channel (Figure 2A). In accord with the availability of the field data, the model extended inside the PG from the channel mouth along the coast in each direction for 3.5 km, and along the watercourse toward the sea for 10 km.



Figure 1: Area under investigation (Hadish watercourse) in Bandar Abbas

The bathymetry file for the area is received from National Cartographic Center of Iran (Figure 2B). As can be seen in Figure (2A) all boundaries along the watercourse were considered as dry boundary. Due to the seasonal nature of this channel, the upstream of the channel is almost always empty. Out inside the PG however three open boundaries were defined including western, eastern, and southern boundaries. Since no measured data for water level was exist near the eastern and western boundaries, the water level data used for these two boundaries of the model where those derived out form the results reported by Ghasemizadeh [9]. In this investigation which has been carried out using MIKE21, the model results derived at Hormoz station were compared with those measured at Hormioz station.

Figure 3 shows the scatter diagram of water level derived from the model and those measured at field. The data presented in this figure are for the period of one month, from 18th of March 2011 till the 17th of April 2011, with the time step of 2 seconds. To show the good performance of the model, fitted trendline for the presented data in graph is provided. The equation represented the fitted trendline and its corresponded R-square are shown in the figure. Considering the fitted trendline equation, and the value of the R-square, it can be concluded that the water level data derived from this model can be used as boundary condition of the present model. Since the area under investigation is located near the Rajaaee Port, those water level time series measured at this station has been applied, for the western boundary condition.

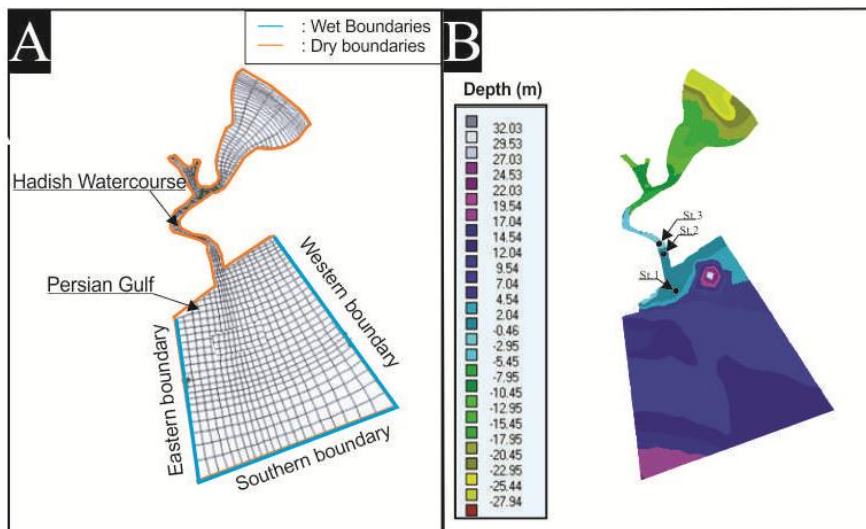


Figure 2: (A) Grid cells, the boundaries, and (B) the Bathymetry of the area

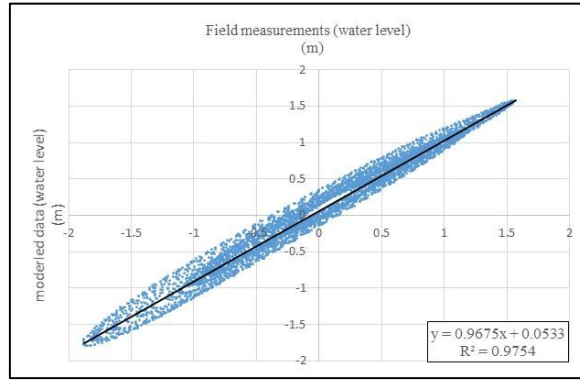


Figure 3: calibrated and validated water level data at Hormoz station

The time step of the model was considered 6 seconds on the basis of the Courant number stability. This number can be calculated using eq. (1).

$$C_r = 2\Delta t \sqrt{gH \left(\frac{1}{\Delta x^2} + \frac{1}{\Delta y^2} \right)} < 4\sqrt{2} \quad (1)$$

in which g is gravity in m/s^2 , Δt is time step in second, H is water depth in m., and $\Delta x, \Delta y$ are the size of grids in x and y direction respectively in m. [10].

The threshold depth for the area, indicating the border between the wet and dryness cell, has been taken to be 0.01 meter. The vertical eddy viscosity parameter adopted for the modeling is $5 m^2/s$ through calibration. Since this study does not involve salinity and/or temperature transfer, the horizontal eddy diffusivity parameter doesn't take into account.

The bed roughness, in which its value can be expressed by Manning's number, should be adjusted as calibration parameter. The value between 0.016 and 0.04 is recommended by the Delft3D manual [11] for this parameter. Since the bottom of the watercourse is mainly covered by cement and stone the Manning's coefficient of friction is suggested to be relatively high. To achieve proper value for bed roughness, several simulations had been carried out with different Manning's number, and the water level data derived from the simulations were compared with the those water level time series, measured at Rajaaee Port station.

Figure 4 shows the water level results derived from three different simulations using the coefficient values of 0.02, 0.03, and 0.04 for Manning's number. Measured water level data is presented as dotted line in the figure. As it can be seen in the figure, employing value of 0.02 for the simulation, the model can reproduce the best fitted water level data with those of the field data.

2.2. Statistical methods to evaluate model results

There are different statistical methods to evaluate model results. Every single method could provide

distinct information in which could be suitable to describe the model results.

Bias, RMSE, correlation coefficient (CC), and Nash-Sutcliffe Efficiency (NSE) are four methods has been used in this study to evaluate model results. These statistical values can be calculated using equations (2) to (5) respectively.

$$Bias = \bar{y} - \bar{x} \quad (2)$$

$$RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^n (x_i - y_i)^2} \quad (3)$$

$$CC = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^n (x_i - \bar{x})^2 \sum_{i=1}^n (y_i - \bar{y})^2}} \quad (4)$$

$$NSE = 1 - \frac{\sum_{i=1}^n (x_i - y_i)^2}{\sum_{i=1}^n (x_i - \bar{x})^2} \quad (5)$$

x_i and y_i in the above equations represents the measured and modeled results respectively. \bar{x} and \bar{y} are the averaged values for x and y .

Values near zero for Bias and RMSE means the goodness of estimated values. Correlation coefficient varies between -1 and 1, and shows the positive or negative correlation between the estimated and real values. NSE values varies between $-\infty$ and 1. Minus values declare the poor estimation of the model [12].

2.3. Introducing pollution to the model

To investigate the emission of pollution in the area, the discharge of pollution should be introduced to the model [13]. Since no confirmed data was found in regard with the discharge of pollution into the watercourse, the average value of $1.36 m^3/s$, reported by Ideh-Pardazan No Consulting Engineers [3], was considered as pollution discharge. To identify the behavior of the pollutant particle, its concentration was considered to be constant in this research.

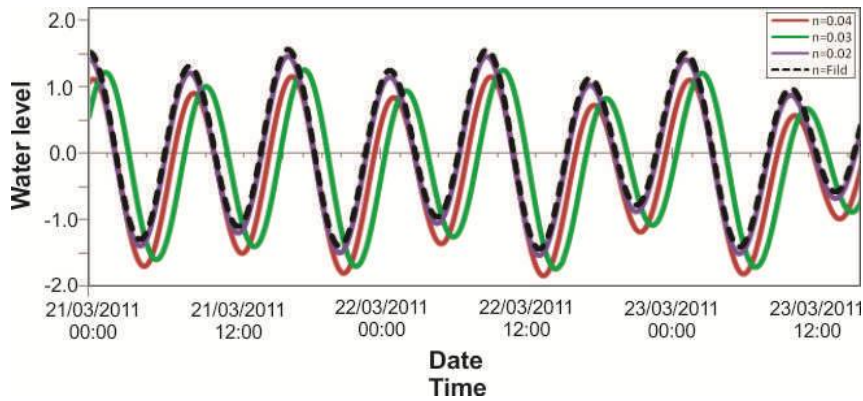


Figure 4: Model calibration with different Manning number

For pollution and particle tracking, Delft3d software is provided with a module called “D-WATER QUALITY”. Trackers in this module are considered to be special types of materials, which are not affected by chemical and biological changes and are merely displaced under hydrodynamic and physical conditions [14]. Using this module, it is possible to track a specific particles pathway, and/or the pattern of pollution in a field of study.

In order to estimate the approximate time in which pollutant needs to reach to the mouth of the channel by the PG, a pollution dissemination modeling was executed. This is to comprise a proper time interval for a released pollution to reach to the mouth of the channel. A tracker particle was released at the middle of the watercourse (ST. 3 in Figure 5).

After executing several models for different periods, it was found that a one-month time period is sufficient for the aim of this research.

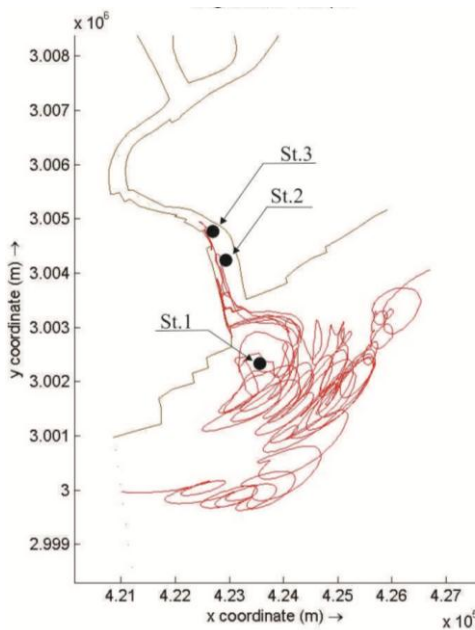


Figure 5: particle tracker simulating for a period of one month

3. Results and Discussion

Scattered diagram of water level data is provided to present the goodness of the model results. Figure 6 shows that modeled water level are in good agreement with the measured water level at Rajaaee Port station. As it can be seen in the figure the data are scattered perfectly along the trend line of $X=Y$.

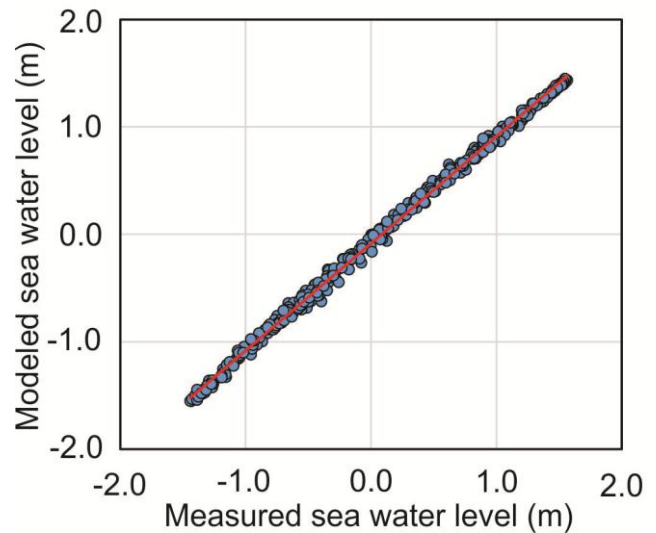


Figure 6: Scattered diagram of water level data

In order to represent the statistical values for the model results Bias, RMSE, correlation coefficient and NSE were calculated for the modeled water level results. Table 1 shows this values.

Table 1: statistical values for the modeled results

Bias	RMSE	CC	NSE
-0.74	0.83	0.001	0.98

All the statistical values confirm that the developed model could provide water level results comparable with those measured in the field.

Figure 7 shows the field water level data at Rajaaee Port (A), water level at three stations 1, 2, and 3 at mouth and along the watercourse (B) (see Figure 2B), and current velocity time series at the same stations(C). This figure shows that the water level along the channel is in phase with the water level at Rajaaee Port. The

high water is about 2 m in Rajaee Port and inside the channel. During the ebb phase however, the whole water of the channel empties into PG. The current velocity (Figure 7(C)) at the mouth of the channel is not with the same phase as that of stations 2 and 3. It could be seen that at the beginning of the flood phase, the strong current at the channel mouth speeds out of the channel toward the PG. The speed reaches up to 30 cm/s. At the end of the ebb phase however, the station at the mouth experiences quite a contrary experience; for the last 2 hours of this phase a relative strong current of about 20 cm/s follows toward the channel. This suggests the longer period for ebb phase, which is also represented in Figure 7(B). Besides, according to the Figure 7(C) the seaward current velocity at the mouth of the channel (station A) is weaker than the flow toward the channel (about 10 cm/s). All of these results emphasize that the channel is ebb dominant, which is in agreement with the local observations.

Figure 8 shows the pattern of current velocity distribution for the two instant times of the low water (A), and high water (B) in the 21st of March 2011. The low tide of 01:40 and the high tide of 23:00 are shown in Figure 7 with dotted lines in order to be recognizable easily. This figure shows that the inflow current velocity at high water is weaker than outflow current velocity at low water. This is also confirmed by the ebb dominance of the watercourse.

In order to trace the behavior of the released sewage in the channel the amount of 1.36 m³/s as a pollutant substance was introduced to the model at all stations. The model was executed for one month. Figure 9 (A to D) shows the results for the first, fourth, seventh, and tenth day of this execution. All the presented pictures are derived out during the flood phase. It can be seen that in the first day of the pollution release, its effect has been felt inside the PG (Figure 9A). In the fourth day of the simulation this amount inside the PG was decreased significantly (Figure 9B). This trend is followed in the seventh day as shown in Figure 9(C). In the tenth day of the simulation (Figure 9D) no trace of pollution can be seen in the PG, and this trend continues for the whole month. Inside the channel however during all these days the maximum pollution is evident.

The entrance of the pollution inside the PG at the beginning of the simulation can be due to the model warm up. This means the model needs at least ten days of simulation for stabilization in regard with pollution.

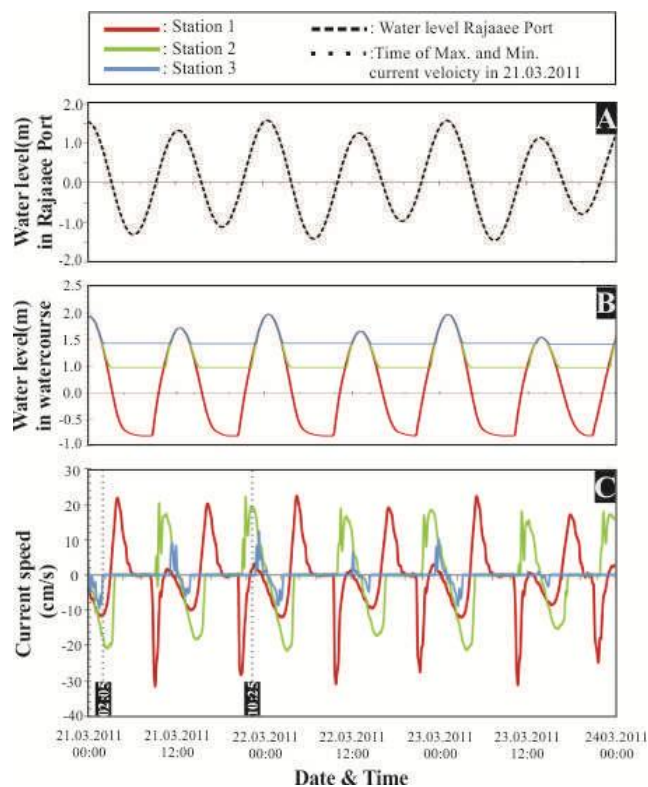


Figure 7: (A) Water level at Rajaee Port, (B) water level at stations 1, 2, and 3 along the watercourse, (C) current velocity time series in the stations 1, 2, and 3

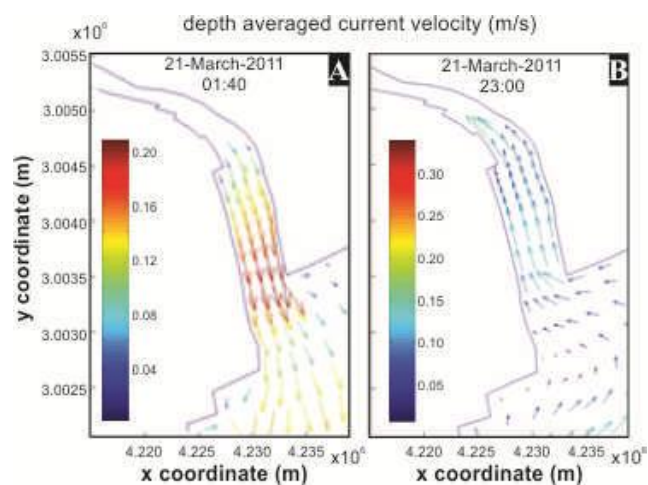


Figure 8: Current velocity pattern inside the watercourse at (A) low tide (01:40 21/03/2011) and (B) high tide (23:00 21/03/2011)

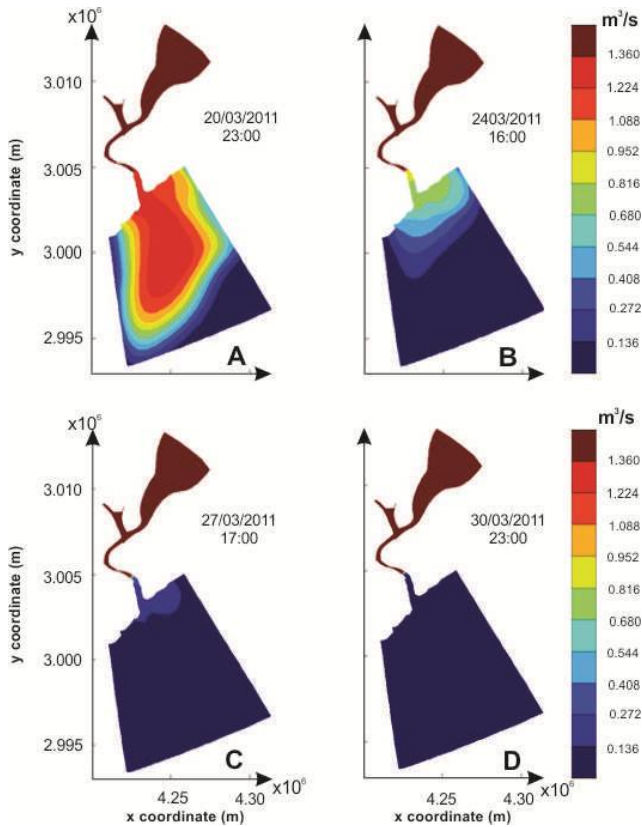


Figure 9: The pattern of pollution in the area under investigation for the first, fourth, seventh, and tenth day of model simulation

4. Conclusion

The watercourse of Hadish in Bandar Abbas was modelled in this investigation, to represent the side effect of release of urban sewage in it. The results show that the channel is merely under the effect of tide, and the upstream of the channel is mostly dry. It was found that the channel is ebb dominant.

Introducing the pollution discharge of $1.36 \text{ m}^3/\text{s}$ to the model along the channel, the model was executed, and the results show that the pollutant mainly remains to the channel and rarely enter to the PG. This finding even if is not evaluated using the actual data, due to the unavailability of the field data, is an alarm for the city of Bandar Abbas and its citizens to think carefully about the release of sewage in this watercourse and find a solution to restore this watercourse.

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