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Minimize the negative impact of oil contamination on Abu Dhabi power and desalination plants

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Abstract

The water resources in the Arab Gulf Region are very limited. The situation of the gulf area is dramatically more serious with the increasing population and much lower rainfall. Power and desalination plants are extensively built in the region to overcome the water shortage and provide power. Abu Dhabi Emirate of United Arab Emirates has five large power and desalination plants with a total capacity of 550 Million Gallon Water and 5000 Mega Watt per day. The heavy traffic of the oil tankers in the Arabian Gulf increases the risk of oil spillage which may reach the seawater intakes of one or more plants sited on seashore or in lagoons. Oil contamination of seawater intakes can affect the quality of the desalinated water and may cause the shut down of the plants in most cases. As the desalinated water is becoming a strategic product it is very essential to protect the plants from any oil contamination could reach their seawater intakes from any source of oil pollution like oil spill accident and leakage from oil terminals. Oil protection measures are installed at the seawater intakes of Abu Dhabi power and desalination and are deployed in the contingency events. The Water and Power Research Center of Abu Dhabi Water & Electricity Authority developed a powerful and effective early oil spill warning system to assist and support the plants by providing the plant managers with the trajectory and concentration of oil spill which may attack the plants. The advantage of the oil spill warning system is to give a warning signal in advance to the plant which may attacked by the oil spill so the oil protection measures can deployed and used to prevent the oil slick from approaching the seawater intakes of the plants.

The paper describes the developed oil spill warning system in Abu Dhabi. A case study on oil spill accident occurred in Abu Dhabi waters is used to demonstrate the application of oil spill warning system. The oil protection measures installed in Abu Dhabi Power and Desalination Plants are described.

Keywords: Oil contamination, Abu Dhabi, Power-desalination plants

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1. Introduction

The marine environment is a primary resource in achieving the social, economic, and strategic objectives of the Arabian Gulf Region. The discovery of oil in the region increases the importance of the Gulf due to the essential need of oil around the world. Nowadays, the Gulf is considered as a main source of water for desalination plants which were built along the coast. The desalinated water is used for domestic use in addition to industrial and agricultural purposes.

The discovery of oil fields in the gulf waters makes the marine traffic in the Arabian Gulf very busy. Large oil tankers, sail in the gulf and transport crude oil and other oil products from the Gulf Region to various parts of the world. The heavy traffic of the oil tankers increases the probability of accidental oil spills. The United Arab Emirates is an example of the Arabian Gulf countries where large desalination plants were built along the Arabian Gulf Coast. The Emirates is a federal country consisting of seven emirates located along the western coast of the Arabian Gulf. Abu Dhabi Emirate is one of these emirates and has four large power and desalination plants. More plants will be built in the future to satisfy the water demands.

It is very essential to prevent oil spills, in case they do occur, from reaching any plant intake to prevent significant reduction in the plant efficiency. To achieve this, the Research Center of ADWEA has setup an early oil spill warning system for Abu Dhabi Emirate to assess the risk of the oil spill reaching any of Abu Dhabi power and desalination plants. These plants are Umm Al Nar, Taweelah and Mirfa Power and Desalination Plants. The advantage of this system is to provide an advance warning signal to the responsible authorities so they are able to take the necessary action and to deploy the oil protection measures at the targeted plant intakes. An overview on the developed oil spill warning system and the procedures to be followed to predict the trajectory and concentration of oil slick will be presented. The established procedures by the research center will be clarified when discussing the case study on oil spill accident in Abu Dhabi waters.

2. Oil spill warning system

The oil spill warning system is a numerical transport model. The hydrodynamic forcing imposed in the model is the tidal flow, which is the main hydrodynamic driving force in the Arabian Gulf and Red Sea. The model considers the additional wind drift of the surface slick. A release of the oil spill in the model is distributed over a number of particles; where the mass of each particle represents the amount of a substance attached to it. The number of particles should be specified in the model. Modeling experience dictates that setting the particle number to 100,000 and 400,000 particles for instantaneous and continuous releases, respectively, is a safe assumption. The vertical dispersion of about 0.001 m^2/s should introduced in the model for well mixed flow condition. Practically, the simulation period is between 5 and 7 days. The tidal flow in the oil spill warning system is generated by the relevant hydrodynamic model simulates the tidal movement in the study area. Wind forecast during the simulation period should be introduced in the model to simulate the effect of the wind drift on the slick. The concentration distribution in the slick is computed by the process of spreading (due to gravity, viscosity and surface tension) and the turbulent diffusion. Because time is very critical in the oil contingency it is very important to know as quickly as possible how the slick moves and if it will attack one of the plants. To do the prediction as quick as possible the hydrodynamic models used for the flow simulations should be available and ready for use in case of oil spill occurs.

3. The developed hydrodynamic models in Abu Dhabi

As mentioned above, the hydrodynamic models are essential for the oil spill warning system and should be available and ready for use in the contingency event. A number of calibrated and verified hydrodynamic models that simulate the Arabian Gulf waters and the waters around the Abu Dhabi power and desalination plants were developed using Delft3D software package of Delft Hydraulics. Fig. 1 shows a general layout of the areas covered and simulated by these models.

The hydrodynamic models provide the oil spill warning system with the flow patterns during the simulation period of the oil slick. Selection of the relevant hydrodynamic model for the study depends on the location of the oil release. The Arabian Gulf Model (AGM) simulates the tidal movement in the Arabian Gulf was developed. The Region Model (RGM) simulates the flow patterns in the United Arab Emirates waters were nested in the Arabian Gulf Model. For each one of the Abu Dhabi Power and Desalination plants a hydrodynamic model was developed and simulates the detailed flow pattern in the plant vicinity. Figs. 2 and 3 show general layout of the Arabian Gulf (AGM) and the Region (RGM) Models, respectively.

4. The procedures of oil spill modeling

Once an oil spill accident occurs, the following procedures should be followed to model the spill trajectory and the oil concentration:

4.1. Data collection on oil spill

Reliable information on oil spill accident is very important for reliable modeling of the

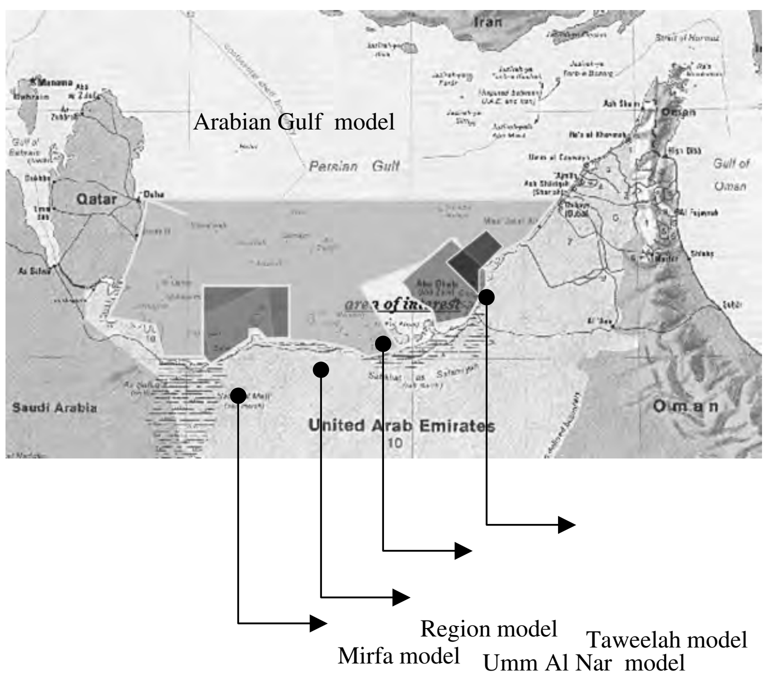

Fig. 1. General layout of the developed hydrodynamic models in Abu Dhabi.

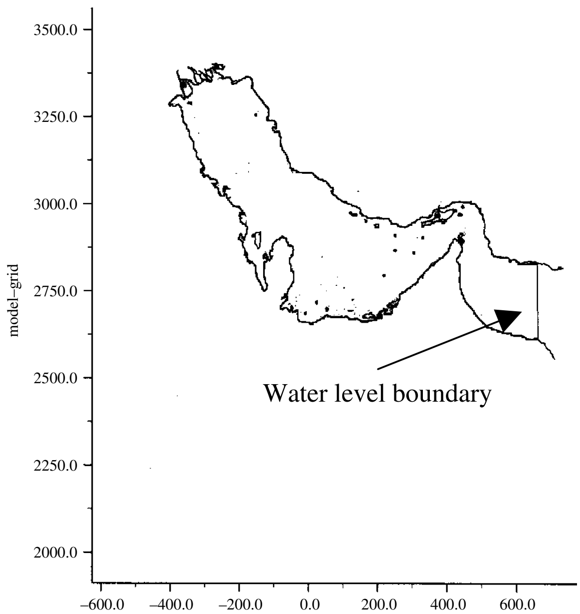

Fig. 2. The AGM model.

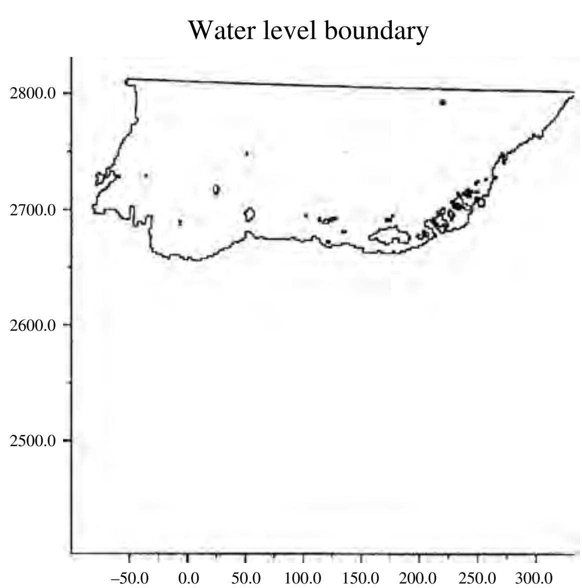

Fig. 3. The RGM model.

spill trajectory. The data set consists of the location and type of the spill, start time of the release, and the amount of the released oil.

4.2. Wind forecast

Wind conditions (speed and direction) influence the advection and transport of oil spill. The wind conditions when the oil is released and wind forecast for about 5–7 days after the release should be obtained from the meteorological authority and introduced in the oil spill model.

4.3. Selection of the relevant hydrodynamic model

The tidal flow, which is important for the transport of oil spills, is simulated with the hydrodynamic model. The location of the oil spill determines the relevant hydrodynamic model to be used to fit the spill in the model grid. If the spill is released in the open sea outside the United Arab Emirates waters the AGM model is used. If it is released inside the United Arab Emirates waters the RGM model is used. From the flow simulation with either the RGM or AGM models a decision will be taken regarding the need for consecutive runs using one of the detailed models developed in the vicinity of the plants. This is done if the simulation shows the spill will approach the shore or the plant.

4.4. Hydrodynamic model run

The flow patterns in the study area should be simulated with the selected hydrodynamic model. The simulation period consists of the period as specified in the oil model (5–7 days) in addition to 2 days of model spin up precede the start time of oil release.

4.5. Coupling of the flow patterns with the water quality model

The flow patterns generated by the hydrodynamic flow model are then coupled with the oil spill model to enable to use the flow pattern as input in the oil model.

4.6. Setup the oil spill model

After the coupling process the other input data and parameters should be introduced in the oil spill model. The start time for the oil release is automatically taken from the hydrodynamic model. The simulation period, time step and the geographical location of oil release should be specified in the model. The spill size presented by the radius of the spill is then determined by the model from the spill volume and the oil viscosity. The amount and rate of oil release should be input in the model. The time series of the wind conditions at the time of release and during the simulation period should be introduced in the model. The evaporation rate is specified based on the oil type. In case of crude or heavy oil the evaporation rate can be set to Zero. In case of light or product oil the evaporation rate can be obtained from oil properties available in the literature or in the oil web sites. The location of the areas of interest (i.e. intakes of the power and desalination plants) should be introduced in the oil spill model as observation points. It will enable obtaining the time series of concentration of the oil slick in order to determine the arrival time of the oil at these locations.

4.7. Model results

The output files from the simulation with oil model should be processed and analyzed. Two dimensional plots showing the area of interest and the predicted location of the oil spill at any specified time frame can be obtained. These can then be used to generate an animation of the oil spill trajectory over the simulation period. Time series plots of oil concentration during the simulation period can also be obtained at the specified observation locations. These plots give an indication of when a particular location would be affected and the amount of oil concentration at that point.

4.8. Reporting

The results of the oil modeling and conclusions should be summarized in a technical report. Due to the urgent needs a standard format of this report should be made available on the computer to safe time.

The estimated times for the completion of each of the mentioned processes is as follows:

- The estimated time for oil and wind data collection is about 1 hr after the request for the study is received.
- The selection of the relevant hydrodynamic model takes about half an hour.
- The estimated simulation time of the hydrodynamic model depends on the type of model to be used. Generally, the estimated run time of the hydrodynamic flow model is not more than 45 min.
- The estimated time for coupling the flow pattern generated by the hydrodynamic model with the oil model is about 5 min.
- The estimated time for the oil spill model setup is about 30 min.
- The oil model simulation will take about 15 min (on average).
- The estimated time for processing and creating the plots and animation is about 1 hr.
- The estimated time for issuing the report is about half one hour.

As it can be seen going through the entire procedure, starting from receiving the request for the study until the report is ready will take about 4–5 hrs. It gives ample time to send a clear warning to the plant which may be attacked by the oil slick.

5. Case study on actual oil spill in Abu Dhabi

On January 24th, 2000 an oil tanker named Ghazeya was sunk offshore Abu Dhabi Emirate causing oil to spill in the Gulf waters. Fig. 4 shows the location of this oil spill.

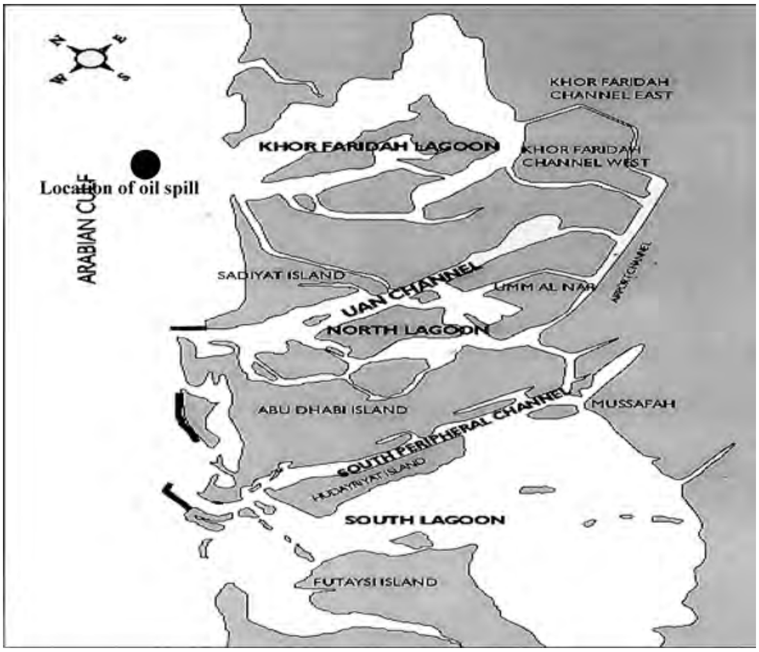

Fig. 4. Location of the oil spill.

Relevant information on oil spill was given by the Abu Dhabi Coast Guard. The Location of the spill was 7 sea miles North East of Abu Dhabi Island at 24° 38.8′ N and 54° 24.3′ E. The time of start of release was on January 24th, 2000 at 10:00 am and the tanker capacity was 900 tons of fuel oil. The wind conditions when the accident occurred as well as the wind forecast for 5 days after the start of oil release was provided by the Abu Dhabi Meteorological department.

The Region Model (RGM) covers the waters of the United Arab Emirates was selected for flow simulation based on the oil spill location. The simulation period of the flow model was 7 days including 2 days for model spin-up. The simulation started on January 22nd, 2000 at 10 am and stopped on January 29th, 2000 at 10 am. The time step was taken as 3 min which gives a good Courant number to guarantee the numerical stability. The flow field from the RGM model was coupled with the oil spill model to provide it with the flow pattern during the simulation period. The geographical location of the oil spill was introduced in the model. The wind drag coefficient was taken as 3% and the wind conditions obtained from the meteorological department were introduced in the model. The evaporation rate was set to 0 because the released oil was heavy oil. The spill size was determined by the model from the release volume and the oil viscosity. The locations of interests were specified in the model. The oil spill model was executed and the output was processed. Fig. 5a and 5b show the predicted location of the oil spill after 12 and 24 hrs from the start of oil release, respectively.

The above figures showed that the slick was closer to Sadiyat Island, after 12 hrs from the oil release, and it moved further, hit Sadiyat Island and went through the North lagoon. For the location of the Sadiyat Island and North Lagoon, see Fig. 4. Fig. 6 shows the time dependent concentration at Sadiyat Island as computed by the oil spill model. The figure shows that the oil slick

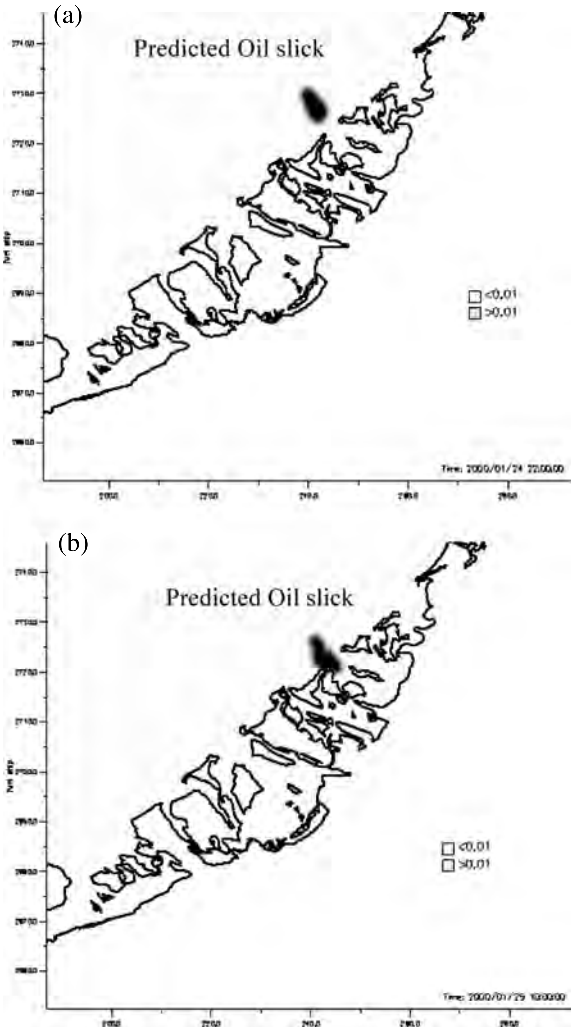

Fig. 5 (a) The prediction of oil spill location 12 hrs after release. (b) The prediction of oil spill location 1 day after release.

reached the island after 20 hrs following the oil release. The maximum concentration when it reached the island was about 0.025 kg/m^3. The computational results and the animation covered the simulation period showed that the oil slick did not reach any of the intakes of the Abu Dhabi power and desalination plants. The study was carried out in about 4 hrs starting from collecting the relevant information and ending with a report to the officials.

6. Conclusions

Oil spill modeling is a very powerful tool for predicting the transport and concentration of oil in a contingency event. The oil spill early warning system presented here requires two types of models; a hydrodynamic one to describe the flow conditions and the particle dispersion oil spill model that follows the spread of the oil spill accordingly. Wind conditions are important in the prediction of the oil spill trajectory. The effect of wind on the flow pattern is simulated in the hydrodynamic model and the wind drift of the surface slick is simulated in the oil spill model. The accuracy of the wind data is very important for the accuracy of the model prediction. The time for predicting an oil spill trajectory in a contingency event is estimated at about 4–5 hrs starting from receiving a request for the study until an incident report is ready. This is ample time for the responsible authorities to act accordingly in advance to prevent the oil from reaching strategic locations such as power and water desalination plans' intakes and deploy the oil protection measures, if needed, before the oil slick can reach the plant.

7. Recommendations

It is recommended to develop a good cooperation between the water and power research centers in the Arab Countries generally and Arabian Gulf Region, specifically. The cooperation between the research centers will allow the exchange of knowledge and experience in the field of desalination plants.

It is strongly recommended to develop a global oil spill warning system in the Arabian Gulf and establish a good network between

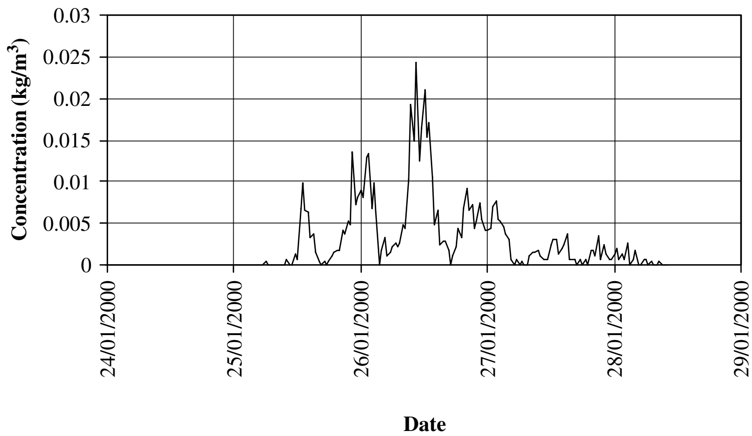

Fig. 6. oil concentration at Sadiyat Island.

the research centers in the Arabian Gulf Region. This will enable the prediction of the oil spill trajectory, if it occurs and give warning signal to the important locations along the coast of the Arabian Gulf, which may be attacked by the spill. The oil spill and wind data and the results of the study should be shared between the research centers in the region.

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