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Dispersion model for assessing oily components of produced water discharges from South Pars Gas offshore

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The discharge of produced water accounts for the largest volume of waste associated with offshore oil and gas production operations. With the development and expansion of Iran's offshore gas reserves in the South Pars fields, there is concern over the potential long-term impacts of produced water discharges in the Persian Gulf. To deal with this emerging issue, the present study focused on modeling and assessment of environmental impacts associated with produced water discharges based on the integration of Gulf hydrodynamic and oily components dispersion models. It provides three-dimensional hydrodynamic input to a Random Walk model focused on the dispersion of oily pollutant components within the produced water effluent stream at a regional spatial scale. In this paper at first the quantity and quality of produced water are measured and reported for one year and some statistical reviews has done. Determination of the oil content of effluent water - Extraction and infra-red spectrometric and OSPAR Reference Method which is the standard method for dispersed oil in produced water analysis in the UK for both oil and gas facilities was used as standard method. Advection, diffusion and fate of oil spills by wind and tidal currents and transport are indirectly taken into account in this study. Hydrodynamic, oil spill and path of the oil pollutants in Offshore Gas Platforms in South Pars Gas Field in 3 month has been simulated in a few scenarios. The results of modeling in this research approved the risk of oily components pollution nearby of onshore ecosystems through 3 months.

Key Words: Modeling, Dispersion, Oil, Offshore, Persian Gulf

INTRODUCTION

The most significant energy development project, the South Pars field, produces about 44 percent of total natural gas in Iran. Discovered in 1990 and located 62 miles offshore in the Persian Gulf, South Pars has a 24-phase development scheme. Phases 1-10, which are operational and are allocated for the domestic market for consumption and reinjection for EOR Produced water is the largest effluent discharge associated with South Pars offshore gas production. (Fig. 1&2) The total volume of produced water effluent is expected to increase with future anticipated development of offshore gas reserve. The environmental impact potentially which is caused by produced water is related to the fate and transport of its individual components including organic and inorganic compounds (e.g., petroleum hydrocarbons, heavy metals, nutrients, natural radionuclide), as well as the formation water and treating chemicals. Although produced water discharges are associated with rapid dilution and low-to-trace levels of pollutants, the potential for cumulative toxic effects under regional ocean currents warrants a need to assess the long-term risks on the marine ecosystems Recently, the increasing development of economy has considerably raised the demand for fossil fuels all over the world. Consequently, oil spill disasters in coastal areas, which may be the result of oil production or transportation, have become one of the most serious threats against marine environment. Understanding the nature of oil spills in coastal areas plays a crucial role in alleviating destructive impacts of oil spill disasters on marine environment [1]. Produced water consists of water naturally present in the oil and gas reservoir (formation water); flood water previously injected into the formation, and/or, in the case of some gas production condensed water. Produced water is part of the well stream together with oil and/or gas. Oil and/or gas are separated from the produced water on the production platform. The produced water is treated to reduce the dispersed oil content to below the regulatory maximum limit of 40 mg/1, set by OSPAR, before it is discharged from the production platform.

Typical produced water flow diagrams of studied platforms are shown in Fig.3. The package is designed to process a feed rate of 2000 bpd liquids and to reduce suspended oil in water content of the separated water to 40 ppm wt. max.

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Fig. 1. A typical platform.

Fig. 2. The South Pars Gas Field location

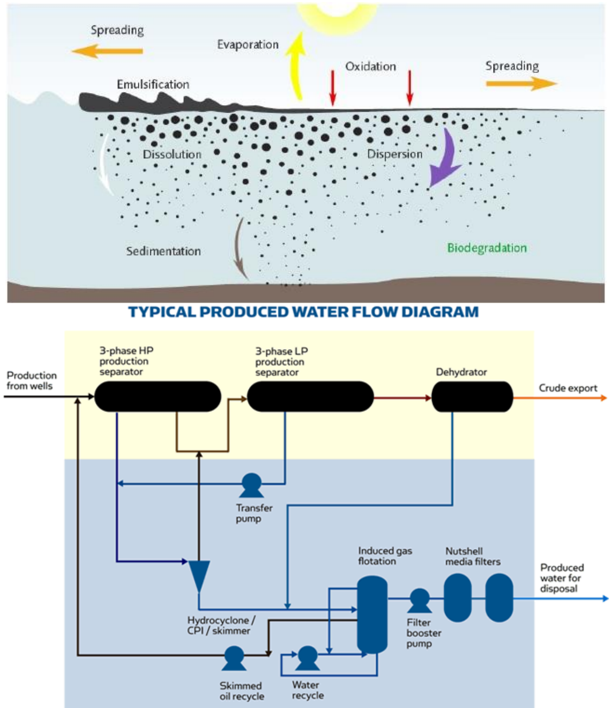

Fig. 3. Typical produced water flow diagram of platforms and oil spills changes in Sea.

MATERIALS AND METHODS

Sampling, preparation and measurement of total petroleum hydrocarbons (TPH) as main oily components in produced water of each platforms has done based on OSPAR Agreement 2005-15 and ISO 9377-2 and ISO 5667-3 test methods[3]. The calibrated GC-FID as an accurate laboratory equipment used for all 52 times analysis of samples and expert personnel through a year carried out reliable tests (Fig. 4).

The MIKE 21/3 software provides three-dimensional hydrodynamic input to a Random Walk model focused on the dispersion of oily pollutant components within the produced water effluent stream at a regional spatial scale.

Fig. 4. GC- FID test equipment and lab experts.

RESULTS

The quantity and quality of produced water are measured and reported for one year and assumed for modeling and some statistical reviews. Table 1 includes oil content of produced water discharge within 3 months on the platform No.5. An average of daily BBL of produced water discharges per each platforms and average of TPH components are shown in Table 1.

Table 1. Data of oil content in platforms no. 5.

Oil	Gasoline (C6-C10)	Diesel (C10-C20)	Heavy Oil (C20-C28)
160	92	53	15
180	101	67	12
177	98	62	17
165	105	51	9
155	80	56	9
145	100	38	7
176	111	55	11
160	115	35	10
166	107	48	11
154	99	41	14
166	111	45	10
170	135	30	5
163	109	41	13
144	88	46	10
130	75	48	17
134	85	35	14
144	92	42	10
136	87	43	6
190	122	60	8
185	129	51	5

Statistical review by SPSS started with Manova method for 8 platforms TPH data in 26 times measurement. It assumed that sampling was random and error of first type was a = 0.05.

This analysis shows that data of platforms are acceptable and useful for mathematical modeling input which is an effective tool for the management of Persian Gulf operational platforms' oily water discharges.

MODEL SETUP

In order to the model input data the bathymetry is used by structure distances of geographical width 2 minute in Southern- Northern direction, and the geographical 2 minute in Western-Eastern direction related to ETOPO1 altimetry data in NOAA site. So by the use of these data in 0.10 structure, the altimetry features of the place is counted and rendered in model (Fig. 5). Tidal surface elevation in Hormuz station utilized for Flow Model FM boundary condition that is shown in Fig 6. Also constant coefficients of oil spill model of Mike 21 are shown in Table 3.

Table 2. Data of platforms.

Platforms	SPD1&2	SPD3	SPD4	SPD5	SPD6	SPD7	SPD8	SPD9	SPD10	SPD11
Water bbl./D	541	167	326	732	1664	389	430	304	2042	1987
Ave. TPH mg/L	43	0	0	155	192	215	330	177	143	208

Table 3. Multivariate Tests.

Effect		Value	F	Hypo-thesis df	Error df	Sig.
Intercept	Pillai's Trace	.999	38754.175^{a}	4.000	197.000	.000
	Wilks' Lambda	.001	38754.175^{a}	4.000	197.000	.000
	Hotelling's Trace	786.887	38754.175^{a}	4.000	197.000	.000
	Roy's Largest Root	786.887	38754.175^{a}	4.000	197.000	.000
platform	Pillai's Trace	1.686	20.822	28.000	800.000	.000
	Wilks' Lambda	.002	109.934	28.000	711.716	.000
	Hotelling's Trace	149.993	1047.271	28.000	782.000	.000
	Roy's Largest Root	148.352	4238.641^{b}	7.000	200.000	.000

a. Exact statistic-
b. The statistic is an upper bound on F that yields a lower bound on the significance level.
c. Design: Intercept + platform

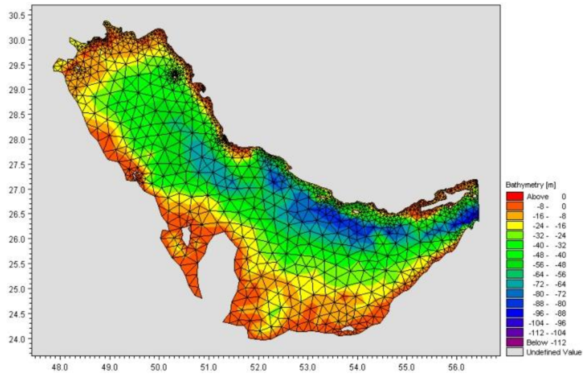

Fig. 5. Mesh Data of Hydrodynamic and Oil Spill model.

Table 3. Constant coefficients of oil spill model.

№	Description	Class	Value
1	Evaporation: Submit number (dim. less)	1	2.6
2	Evaporation: Average molecular weight of volatile fraction of oil (g/mol)	1	60
3	Evaporation: Vapor pressure (atm)	1	0.04
4	Spreading: Terminal thickness (mm)	1	0.005
5	Spreading: Maximum oil-front velocity (m/s)	1	0.4
6	Biodegradation: Decay rate (per day)	1	0.01
7	Emulsification: Rate (s/m^2)	1	2e-006
8	Emulsification: Maximum water fraction (m^3/m^3)	1	0.6
9	Emulsification:Constant Kao equal 3.3 at 293 K (dimentionless)	1	3.3
10	Emulsification: Constant Kao equal 200 at 293 K (dimentionless)	1	200
11	Emulsification: Fraction of asphaltene (g/g)	1	0.01
12	Emulsification: Fraction of wax (g/g)	1	0.05
13	Buoyancy: Density of original oil at 20 ˚C volatile fraction (kg/m^3)	1	950
14	Buoyancy: Density of original oil at 20 ˚C heavy fraction (kg/m^3)	1	980
15	Buoyancy: Grain diameter of oil particles (mm)	1	0.001
16	Photooxydation: Decay rate (per day) at 100 watt/m^2	1	0.001
17	Photooxydation: Light extinction coefficient (1/m)	1	1
18	Dissolution: Rate light fraction (per day)	1	0.1
19	Dissolution: Rate heavy fraction (per day)	1	0.005
20	Vertical dispersion: Fraction of wave height (dim. less)	1	0.1
21	Vertical dispersion: Parameter for wave break	1	0.001

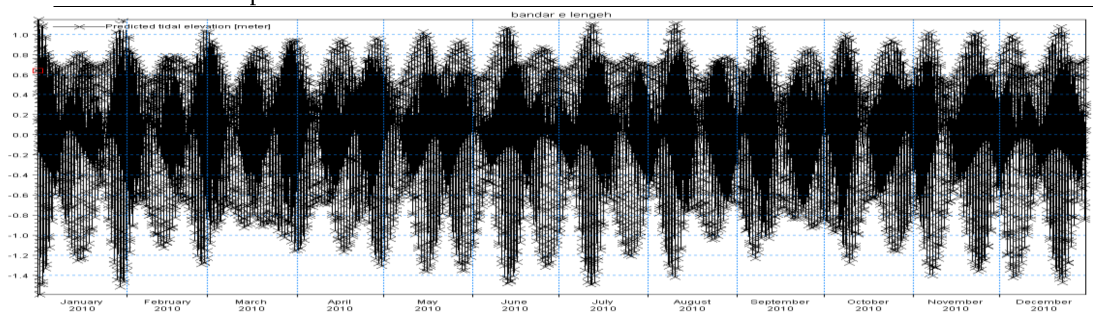

Fig. 6. Tidal elevations at Hormuz station used as boundary conditions for the Flow Model.

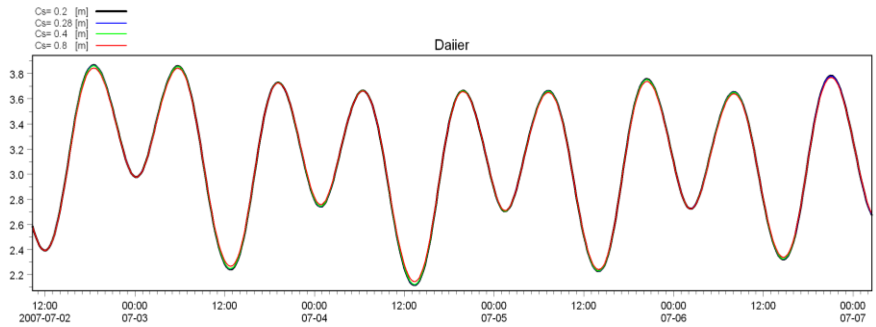

Fig. 7. Model Validation and Sensitive Analysis between Numerical Model and Measurement Data

RESULTS

In this research, hydrodynamic parameters such as tidal surface elevation that measured in Daiier Port have been used for model validation (Fig 6). Comparing numerical results and field measurements shows a good agreement between numerical results and field measurements in Daiier Port. Hydrodynamic results of are shown in Fig 7. Oil dispersion model, which includes hydrodynamic model and qualitative water model from produced water, has been done for a year for each discharge location. Oil spill modeling in Offshore Gas Platforms in South Pars Gas Field is shown in Fig 8. Path of the oil pollutants in Offshore Gas Platforms in South Pars Gas Field is shown in Fig 9.

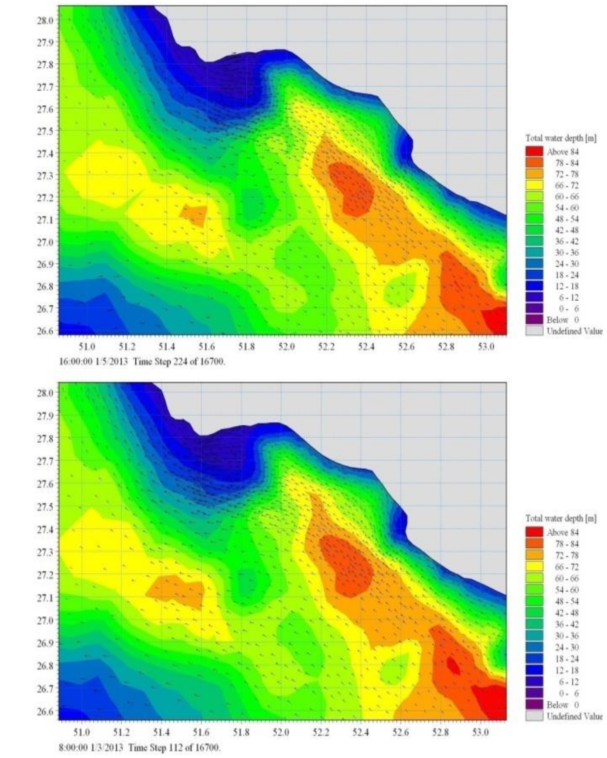

Fig. 8. Flow velocity vectors in the surrounding area of Asalooye.

CONCLUSIONS AND DISCUSSION

Comparing Industry development and growing marine transportation, together with oil spill disasters in the seas and oceans have resulted in contamination of marine environments. Advection, diffusion and fate of oil spills by wind and tidal currents and transport are indirectly taken into account in this study. This study was done on Gas Platforms in South Pars Gas Field in Iran; however there are other platforms belonging to Qatar, so there are actually produced water discharges and pollutants from those platforms, too. Therefore,

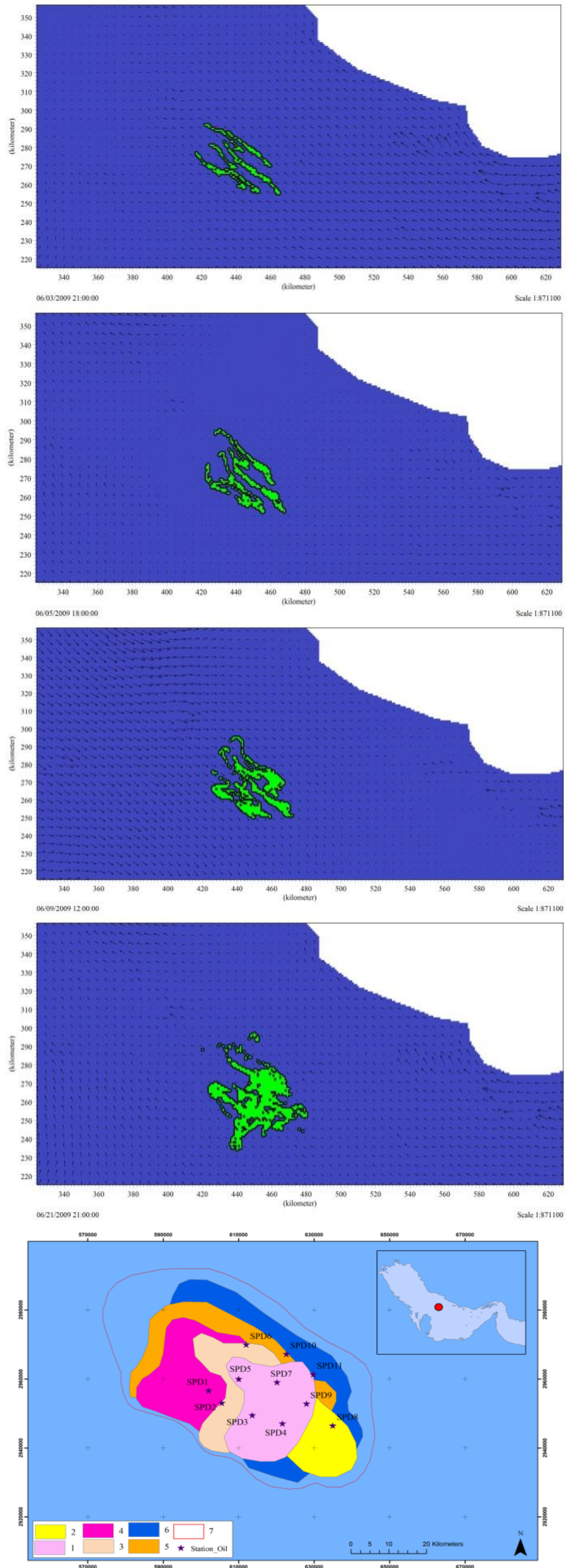

Fig. 9. Path of the oil pollutants in offshore gas platforms in South Pars Gas Field during the simulation period.

future studies can be done on other platforms in South Pars Gas Field and the obtained results can be compared, so better and more accurate results can be achieved.

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