Oil Spills simulation in Rayong coastal area : case study oil spill on 26 January 2022

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Abstract

Oil spills cause severe problems to the environment and the economy. To manage the oil spill problem after it is released into the sea, it is necessary to know the current pattern and wind information. This study aimed to simulate the oil spill in Rayong coastal area on 26 January 2022 using the GNOME models. The GNOME model was calibrated using a satellite image from GISTDA when the severe oil spill event occurred near Samet Island on 27 July 2013. In the case of oil spills at Rayong coastal on 26 January 2022, the results have shown the oil spill will finally move to attack the Khao Leam Ya national park beach, which is around 9 km on the Eastern side of IRPC Industrial Estate, at 1.00 p.m. of 29 January 2022. Although the actual situation, the satellite image from GISTDA showed the oil spill moved to the coastal at 10.35 a.m. on 29 January 2022, faster than the model, about two and a half hours. This preliminary study will lead to further development to be accurate and precise. Further improvements in oil spill modeling should focus on another weathering process of spilled oil. The improvement in the parameterization of oil transport, since the accuracy of the transport process, depends on the accuracy of the circulation and atmospheric models.

Keywords: Oil spills, GNOME model, Rayong

1. Introduction

Oil spill causes serious problems not only for the environment, but also for the tourism and economy of Thailand. Marine Department defines an oil spill as a disaster that releases over 20,000 liters of oil into the sea. From 1997 to 2013, 11 huge oil spill events occurred in the Gulf of Thailand [1]. Therefore, The Pollution Control Department has classified oil spill risk zones in Thailand by the level of risk and the severity of oil spill impacts in the four zones, as presented in Fig. 1 [2]. Zone 1, East Coast of the Gulf of Thailand, where the sites of industrial estates are the highest risk zone. The Chao Phraya River mouth to the Bangkok port is zone 2 (the higher risk zone). The West Coast of the Gulf of Thailand and the Andaman Sea in zone 3 is the high-risk zone. The other specified in the three zones above is zone 4 (the low-risk zone).

For managing the oil spill problem after it was released into the system, the behavior of the circulation pattern in the Gulf of Thailand is an essential knowledge to specify the locations and procedures for capturing the oil spill. Many researches indicated that tidal and wind are the main components of the current in the Gulf of Thailand. Some previous researchers pointed out that tidal currents play a dominant role in the current in the Gulf of Thailand [3 - 9]. The predominant monsoon winds caused eddied, mixing, and water mass exchange in the Gulf of Thailand.

Nowadays, there are a few studies on the oil spill simulation in the Gulf of Thailand. The Pollution Control Department identified the risk areas for the oil spill using the OILMAP 6.4 program in the upper Gulf of Thailand and the eastern part of Thailand [2]. It was found that the pattern of oil spill movement depends on the types and properties of the oil, amount of leakage, wind, tide, and current in the Gulf of Thailand. The oil spill moves to the southwest direction during the northeast monsoon season. On the other hand, the oil spill moves to the northeast direction during the southwest monsoon season [10].

This paper presents the results of oil spill simulation under case study at Rayong coastal area on 26 January 2022. The work reported in this paper can be considered an extension of the study by Polsomboon and Sriariyawat [11 - 12]. The objective of this study is to apply the prediction of the oil spill movement in Rayong coastal area on 26 January 2022.

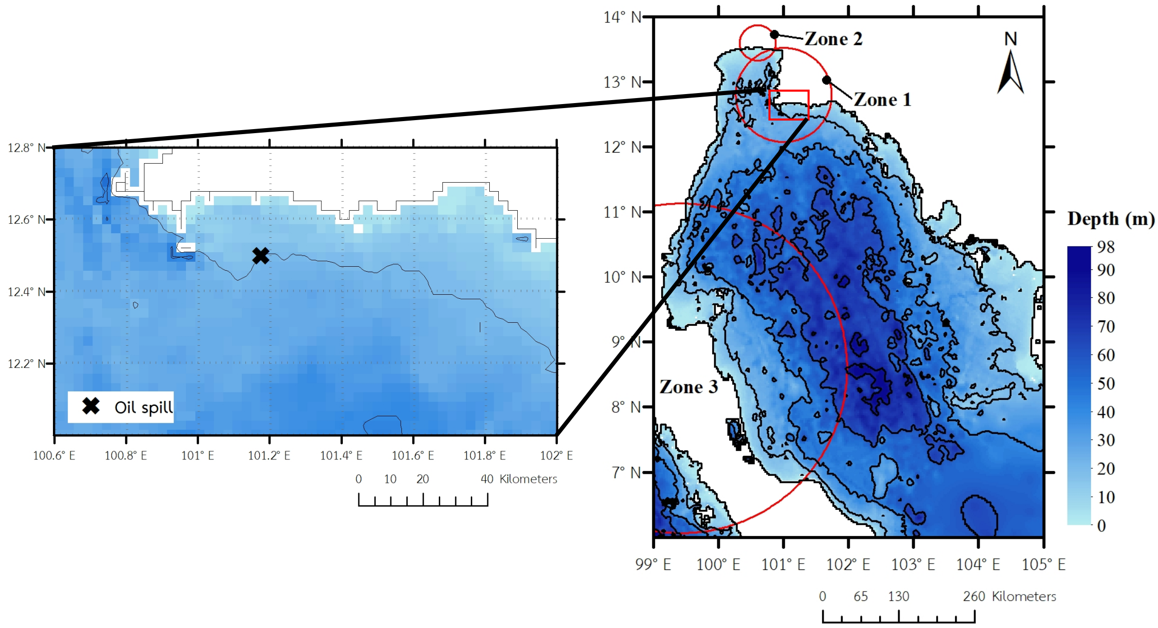

Fig. 1 Oil spill risk zone in the Gulf of Thailand

2. Methodology

The oil spill simulation in this study contained three models. The SWAN model was used to simulate wind to waves, while the current model used the Delft3D model to simulate the current pattern in the study area. Finally, the GNOME model was used to predict the movement of oil spills in the study area. The wave and current input data came from SWAN and Delft3D model as presented in the previous studied [11 - 12].

2.1 Study area

Rayong is a province on the east coast of the Gulf of Thailand with 100-kilometer-long coast. The area covers from longitude 100.6° E to 102° E and latitude from 11.7° N to 12.7° N, as shown in Fig. 1.

The previous study [11 - 12] showed that the annual climate wind rose for 20-year wind time series (1997 to 2016) for this location, as presented in Fig. 2a. It can be seen that winds are predominantly from west-southwest (WSW) to south (S) and northeast (NE) to east (E) directions, but the strongest winds tend to come from the west-southwest (WSW) and northeast (NE) directions.

Offshore wave heights and wave periods were taken from the SWAN model. The distribution of frequency of the significant wave height (Hs) at Rayong in 1997 – 2016 is shown in Fig. 2b. The wave rose indicated that the predominant wave direction was from the southwest (SW) and south (S), accounting for approximately 25% of wave climate in each direction. There was a smaller predominance of waves from south-southeast (SSE) and south-southwest (SSW), occurring for about 15% and 14%, respectively. Most wave periods are around 2 - 5 seconds for the wave period as shown in in Fig. 2c, which means that the waves in this area are mostly wind waves.

The current rose in Fig. 2d indicates that the predominant current direction is from the west-northwest (WNW) and east-southeast (ESE), which account for approximately 37% and 38% of the time. The current speed is about 0 – 0.4 m/s. Tidal is a significant effect on circulation in this area.

2.2 Data used

The bathymetry data were obtained and were interpolated from the GEPCO 30 arc-second grid of the British Oceanographic Data Centre (BODC). The resolution of GEBCO30 is about 30 arc-second (around 0.93 kilometers).

The wind data used as principal input to the GNOME model in this study was the six-hourly time-averaged wind fields (four analyses fields per day, at 00, 06, 12, and 18 UTC) of wind speed and direction at 10 m from the European Centre for Medium-Range Weather Forecasts (ECMWF) [13]. In this study, the ECMWF ERA-Interim data set was used. This is the latest version of the wind data set re-analyses; therefore, it could be considered as the most accurate data. However, the gridded forecasts wind data was unavailable at the oil spill case at Rayong on 26 January 2022. Therefore, we used uniform wind forecast data from Windy to simulate the oil spill movement. Windy is an extraordinary tool for weather forecast visualization. The wind data from the global model from ECMWF [13] that resolution of 9 km and wind animation is based on the open sources project of Cameron Beccario earth.

The current hourly data under tide and wind conditions in this study, simulated from the Delft3D model, were used to input the GNOME model [11 - 12]. The curvilinear grid system of the Delft3D is developed with a 1-kilometer resolution.

The satellite images of oil spill event at Samet Island on 27 and 29 July 2013 from the geo-informatics and space technology development agency (public organization) (GISTDA) were used to calibrate and validate the GNOME model [14].

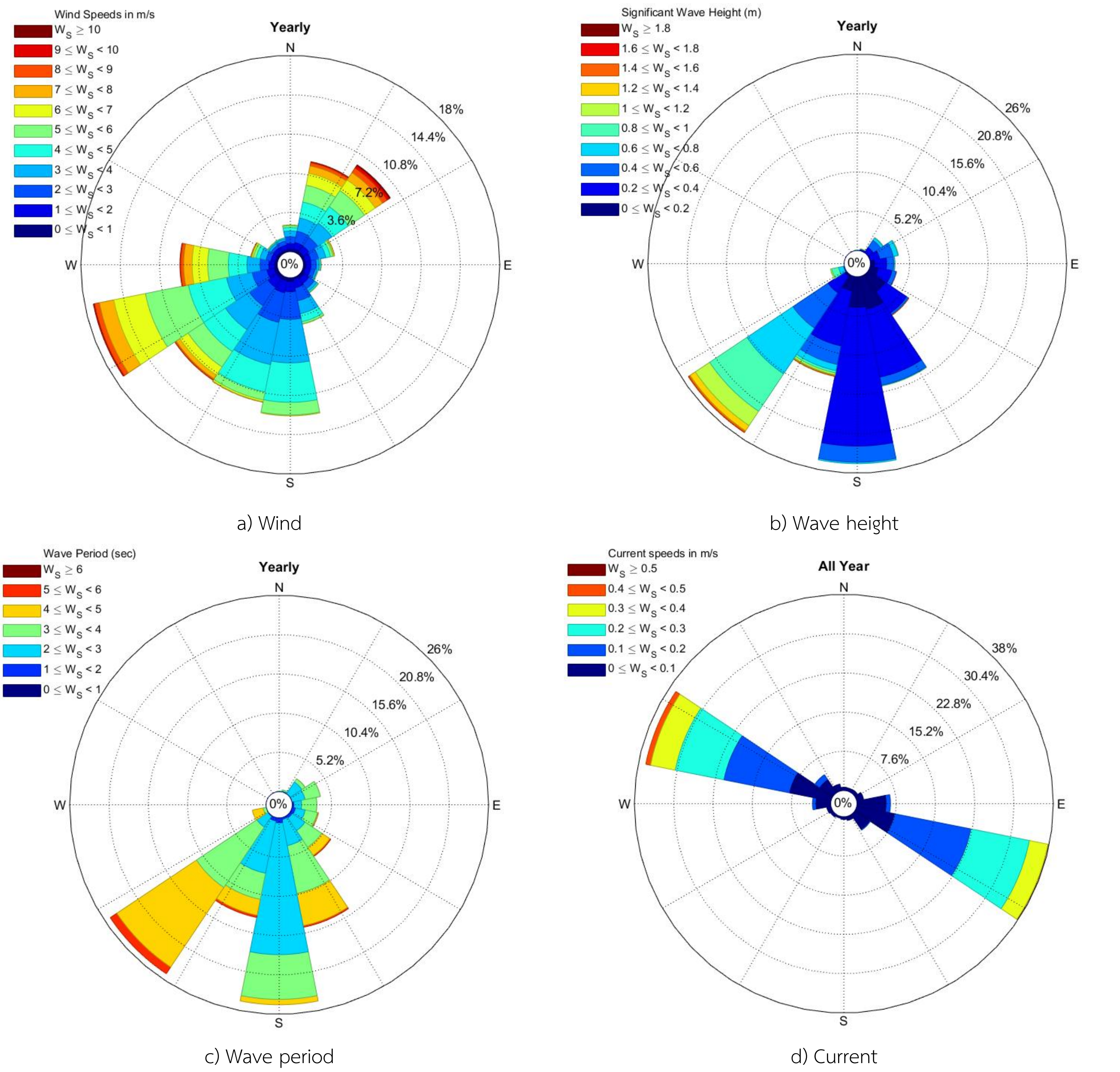

Fig. 2 Wind rose, Wave rose and Current rose at Rayong coastal area

2.3 GNOME model

When oil spills, the physical and chemical characteristics of oil, such as dispersion, evaporation, and sedimentation, interact with the physical and biochemical features of the habitat where a spill occurs. These factors determine how the oil will behave and, ultimately, what will happen to it.

The General NOAA Oil Modeling Environment (GNOME) is the modeling tool developed and used by the NOAA Office of Response and Restoration's (OR&R) Emergency Response Division to predict the possible trajectory of a pollutant that might follow in or on a body of water. For nearly 20 years, GNOME has been used by emergency responders on behalf of the industry, government, and organizations to track oil spills, chemical spills, marine debris, and more.

GNOME uses an Eulerian/Lagrangian spill-trajectory model in which the regional physics are simulated as Eulerian fields within which the slick's Lagrangian Elements move. Within GNOME, the oil is divided into many small particles that move under the influence of ocean currents, wind drift, and turbulent motions. The fate and transport of oil spilled into the marine environment also depend on a suite of physical, chemical, and biological processes weathering. GNOME simulates six product types: gasoline, diesel, medium crude, fuel oil #4, fuel oil #6, and non-weathering tracer.

The basic equation that is used in the GNOME model is a calculation between current, wind, and diffusion of oil at various times, as shown in Eq. (1) [15].

$$\frac{\partial x}{\partial t}=U_c+k_wU_w+D \quad (1)$$

Where $\frac{\partial x}{\partial t}$ is the movement of the particle (oil), U_c is the dynamic driving force (current velocity), k_w is the windage coefficient, U_w is the wind speed, and D is the turbulent diffusion.

2.2.1 Model setup

The GNOME model uses ocean currents, typically from ocean models, and wind from atmospheric models or weather stations to force the movement of oil at the sea surface. This study used the current data under tide and wind conditions from the Delft3D model [11 - 12] and wind from Windy [13] As shown in Fig. 3.

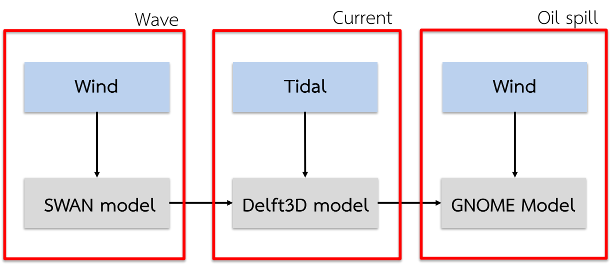

Fig. 3 Flow chart of this study

We used the oil spill case at Rayong coastal area for calibration and validation from 27 July to 1 August 2013. Fifty thousand liters of medium crude were released at latitude 12.5° N, longitude 101.175° E. The accident occurred in the evening, so the release time was approximately on 6:30 p.m.

3. Results

3.1 Calibration and validation

Five difference diffusion coefficients that present the horizontal eddy diffusivity in the water were used for calibrating the GNOME model. The results show that if the diffusion coefficient of oil is high, the oil spreads more widely, as shown in Fig. 4. Therefore, the optimum diffusion coefficient of oil is 5,000 cm^2/s, which we use in this study. However, in this case, the error was about 4 km from the center of the oil spill. However, the results from the model did not spread as widely as the actual.

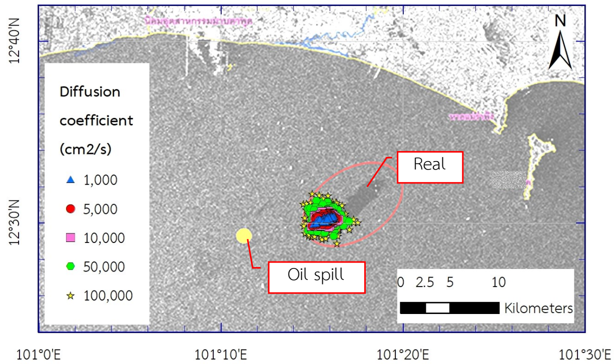

Fig. 4 Comparison of oil spill location with difference diffusion coefficient [14]

For validation, we compared the oil spill location from GNOME with a satellite image on 29 July 2013 at 6:23 p.m. The oil moved to Ao Prao, Samet Island, but error around 2.5 km. However, unlike the actual event, the oil spills did not proceed further behind the island, as shown in Fig. 5.

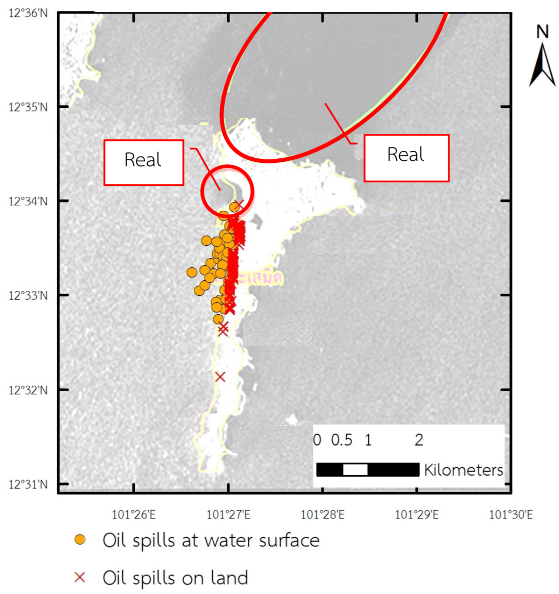

Fig. 5 Oil spill at Samet Island on 29 July 2013 6:23 p.m. [14]

3.2 Oil spill simulation : case study on 26 January 2022

On 26 January 2022, at 00.10 a.m., crude oil of about 400,000 liters leaked from an undersea pipeline about 20 km off Map Ta Phut in Rayong province. The oil spill simulation with the forecasting wind data from Windy.com showed the average wind speed of about 3 m/s and the direction of the wind to the northeast (NE). The oil spill location from the simulation was compared with a satellite image from GISTDA on 26 January 2022 at 10:40 a.m. The model results were closed to the satellite image that moves north, far from the leak point, about *3* km., however the oil spills were not as widespread as the actual event as shown in *Fig. 6*.

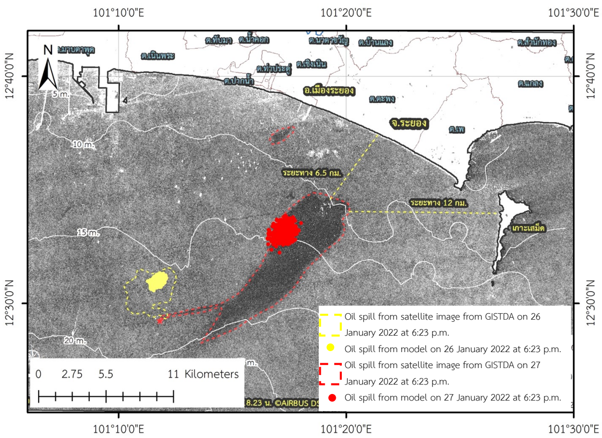

Fig. 6 Comparison of oil spill location from the model and satellite image from GISTDA on 26 January 2022 (yellow color) and on 27 January 2022 (red color) [14]

The first prediction of the model on 26 January 2022 showed the result that the oil spill will attack the beach at IRPC Industrial Estate on 29 January 2022, at 07.00 a.m., around 55 hours after it released as shown in *Fig. 7a*. After tracking the oil spill behaviour, it was found on 28 January 2022 that the wind direction changed from the northeast (NE) to the east-northeast (ENE). Therefore, the simulation had to recalculate, and the result showed that the oil spill will finally move to attack the Khao Leam Ya national park beach, where is around 9 km on the Eastern side of IRPC Industrial Estate, at 01.00 p.m. of 29 January 2022, as shown in *Fig. 7b. However, the satellite image from GISTDA showed the oil spill moved to the coastal at 10.35 a.m. of January 2022, as presented in* Fig. 8. The oil spill location from the model was compared with a satellite image from GISTDA on 27 January 2022 at 18:23 a.m. The results showed that the model's oil spill was in the oil spill's position from the satellite image. But the results from the model did not spread as widely as the actual, as shown in *Fig. 6.*

Fig. 7 The oil spill simulation a) the first run on 26 January 2022 and b) the second run on 28 January 2022

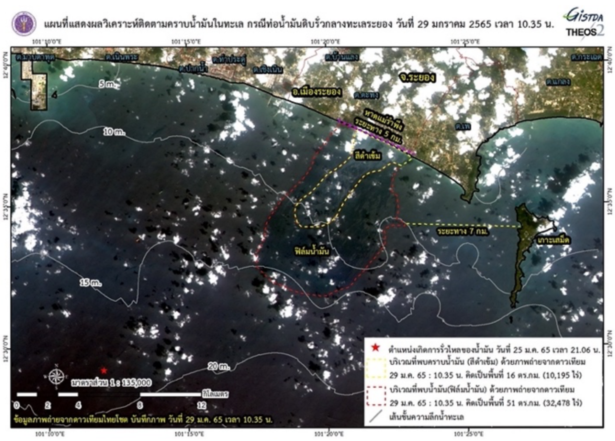

Fig. 8 The satellite image of oil spill on 29 January 2022 from GISTDA [14]

4. Conclusions

On the Rayong coast, the winds are predominantly from west-southwest (WSW) to south (S) and northeast (NE) to east (E) directions, but the strongest winds tend to come from the west-southwest (WSW) and northeast (NE) directions. The predominant wave direction was from the southwest (SW) and south (S). Most wave periods are around 2 - 5 seconds for the wave period, which means that the waves in this area are mostly wind-waves. The tidal is a significant effect on the circulation that the direction of the current movement toward west-northwest (WNW) and east-southeast (ESE).

In the case of oil spills at Rayong coastal on 26 January 2022, the results have shown the oil spill will finally move to attack the Khao Leam Ya national park beach, which is around 9 km on the Eastern side of IRPC Industrial Estate, at 1.00 p.m. of 29 January 2022. Although the actual situation, the satellite image from GISTDA showed the oil spill moved to the coastal at 10.35 a.m. on 29 January 2022, faster than the model, about two and a half hours. This preliminary study will lead to further development to be accurate and precise by adding gridded forecasts wind data from relevant agencies such as the Thai Meteorological Department (TMD).

The basic of the GNOME model is the trajectory model that oil is divided into many small particles that move under current, wind, and diffusion of oil. The fate and transport of oil spilled model that depends on a suite of physical, chemical, and biological processes weathering may be applied for increased accuracy of results. Further improvements in oil spill modeling should focus on another weathering process of spilled oil, such as the drift and evolution of oil spills or sedimentation. The improvement in the parameterization of oil transport, since the accuracy of the transport process, depends on the accuracy of the circulation and atmospheric models.

Oil spill response aims to minimize damage and reduce the time for environmental recovery. So, for the oil spill forecasting on the incident, the pathway of the oil spill, and the location where the oil spill will attack the beach are necessary. However, the time it takes for the simulation to affect oil spill prevention and respond to the manipulation's preparation. There will be no time to prepare the oil defenses heading for shore if it takes too long.

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We want to thank the geo-informatics and space technology development agency (public organization) (GISTDA) for the satellite image of oil spill events, the British Oceanographic Data Centre (BODC) for the providing the bathymetry data (GEBCO30) of the Gulf of Thailand, the European Centre for Medium-Range Weather Forecasts (ECMWF) for the wind data.

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