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Research Article

Assessing the Impact of Ship-Sourced Marine Pollution on Filyos Port

Cihat Aşan

Maritime Transportation and Engineering Department, Maritime Faculty, Piri Reis University, İstanbul, Türkiye

* E-mail: casan@pirireis.edu.tr

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Abstract

In 2021, Türkiye launched the Filyos Valley Project, a strategic initiative with the potential to serve as both a central hub for the transfer of Central Asian oil to the West and as a logistical bridge between China and Europe. Located near the city of Zonguldak in northern Türkiye, this project encompasses a range of logistical components, including the extensive and high-capacity Filyos Port, which is the country’s third largest port. The port is situated in close to the Sakarya Gas Field in the Western Black Sea, Türkiye's largest natural gas production area, and currently serves as a base for natural gas drilling ships and their support vessels. Filyos Port plays a crucial role in Türkiye's energy security due to its strategic location near the Istanbul Strait, a key convergence point for maritime traffic in the Black Sea. However, this proximity also poses a significant risk; pollution from a maritime accident along the approach routes to the Strait could severely disrupt the port's operational capabilities. This study aims to analyse the behaviour and spread patterns of ship-sourced oil pollution near Filyos Port and to determine the timeframe within which the port would be exposed to such pollution. This research offers a comprehensive framework for port authorities to develop effective contingency plans, ensuring operational sustainability and enhancing the region’s energy security by mitigating marine pollution risks.

Keywords: Filyos Port, Oil Pollution, Maritime Business Management, Pollution Response

Introduction

Filyos Turkish Petroleum Port was established in the Western Black Sea in the north of Türkiye to meet the operational and logistical requirements for the natural gas production and processing facilities to be located in the Filyos Industrial Zone and the pipelines that will connect these two facilities, which are required within the scope of the development project in the Sakarya Gas Field, where the country's most important hydrocarbon discovery was made in the Black Sea (TP-OTC, 2024) (Figure 1, 2).

Started in 2016, Filyos Port was put into service on 04 June 2021. Located within the borders of Zonguldak province, Filyos Port is the largest port in the Black Sea with an annual handling capacity of 25 million tonnes. The port, which is shown in Figures 3 and 4, also can handle various sizes and types of ships at the same time. A port of this size and capacity, which has to be used by 16 ships in the Turkish Petroleum Corporation (TPAO) inventory and other support vessels numbering up to 50 in the natural gas extraction operations, has also been effective in TPAO's choice of the area behind the port as a natural gas processing facility (Turan and Çelikoğlu, 2023). The Coastal Logistics Centre, located within the boundaries of Filyos Port and used in the construction phase, is operated by TPAO subsidiary Turkish Petroleum Offshore Technology Center (TP-OTC) Joint Stock Company and Sakarya Gas Field Development Project is operated by TPAO (BAKKA, 2018).

Located 15 kilometers away, two power plants have a combined capacity of 3,100 megawatts. Additionally, multimodal transit options such as a railway connection, neighboring highways, and an airport will be accessible. In addition to the two prominent steel companies located nearby, Filyos will cater to vendors and manufacturers in the vicinity of Türkiye's capital, Ankara, as well as service the countries along the Black Sea coastline and Eastern Europe. Upon project completion, it is anticipated that congestion at ports in the Istanbul region will be reduced (BAKKA, 2020).

The maintenance of the operational sustainability of such an important structure in terms of the energy security of the country is equally important. The proximity of Filyos Port to the Istanbul Strait, which is the final gathering point of the current maritime traffic in the Black Sea, reveals its sensitivity to possible marine pollution caused by this traffic. Considering the prevailing oceanographic and meteorological conditions in the Black Sea, the possibility of oil pollution spreading to Filyos Port and preventing the entry and exit of the TPAO vessels stationed there, and thus their mobility, seems to be quite high. The objective of this study is to examine the potential impact of ship-sourced oil pollution near Filyos Port based on a constructed scenario.

To align with this objective, the Potential Incident Simulation, Control and Evaluation System (PISCES-II), a decision support system for maritime incidents, is employed to simulate the incident. This system elucidates the spread of oil pollution, its behavior at sea, and the timeline for its arrival at Filyos Port.

Fig. 1. Geographical Position of Filyos Port (Google Earth, 2024).

Fig. 2. Satellite View of Filyos Port (Google Earth, 2024).

Fig. 3. TPAO Ships at Filyos Port (TP-OTC, 2024).

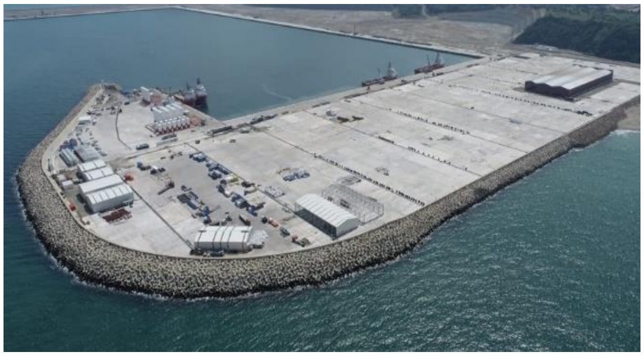

Fig. 4. Present View of Filyos Port (TP-OTC, 2024).

When previous studies were examined, it was determined that the spread patterns and behavior of different types of pollutants on the sea surface were modeled with different simulations, and in some studies, intervention techniques for this pollution were also optimized. In this context, Aydın and Solmaz (2019) modeled and evaluated the M/V Lady Tuna ship incident and oil pollution response operation that occurred in Çeşme Bay in the south of Türkiye, using the Potential Incident Simulation Control and Evaluation System (PISCES-II). Their conclusion demonstrated the importance of adequate information sharing and rapid reaction time for marine pollution response operations. Using Oil Map software, Koroglu and Kabdasli (2011) simulated the spread pattern of 200 tons of crude oil pollution near Türkiye's Istanbul-Haydarpaşa port and examined the effectiveness of dispersant use on pollution in the same study. During the Lebanon Crisis, the findings of the simulation that emerged from PISCES-II were widely confirmed. During this time, the simulated oil-spilling area was continually compared with acquisitions that were gained via satellite surveillance (Perkovic et al., 2008). The study also detailed the modeling approach, which can be applied to similar endeavors. A study conducted by Acir et al. (2011) simulated the potential spread of an oil leak and its arrival at the Turkish coast along the eastern Black Sea coastline following a tanker accident. They achieved this by utilizing a PISCES II simulator. Can et al. (2005) conducted a study that simulated the spread of oil in the Rumeli Kavağı-Istanbul Strait area, similar to an Oil Tanker Nassia accident by using STAR-CD software for this simulation. A different study examined the outcomes of a simulated oil spill track in the Arabian (Persian) Gulf using MIKE 3 HD/SD-combined 3-D rectangular hydrodynamic and oil spill models by Elhakeem et al. (2007). Reed et al. (1999) conducted analyses on certain probable spill scenarios for drilling operations scheduled offshore of Namibia. The analyses were performed using the SINTEF Oil Spill Contingency and Response (OSCAR) 3-dimensional model system. Concerning the response assets and procedures, Ventikos et al. (2004) reported the operational synthesis of major oil spill intervention methods and equipment in their study. From a related perspective, a separate study conducted by Aamo et al. (1997) demonstrated the utilization of weathering research data to develop tailored contingency plans for individual sites, in conjunction with the modeling of potential oil spill scenarios. Sidorovskaia et al. (2016) present an innovative approach for quantifying the influence of human activities on the marine animal population. The paper presents the findings of an investigation into the changes in regional population dynamics after the Deepwater Horizon accident. The data used in the study was collected by passive acoustic monitoring in the affected area both before and after the oil spill. The study specifically focuses on sperm and beaked whales. Asif et al. (2022) analyze the vulnerability of coastlines to the consequences of oil spills and the possible influence of seasonal variations on the natural dissolution of oil. The study conducted by Jørgensen et al. (2019) presents the European Union (EU) Horizon 2020 research initiative called "GRACE" which aims to comprehensively investigate the detrimental impacts of oil spills and evaluate various marine oil spill intervention technologies in the icy environment and ice-laden locations of the North Atlantic and the Baltic Sea. Sun et al. (2023) developed a portable laser-induced fluorescence lidar detection system for unmanned aerial vehicles, consisting of a transmitting and receiving module, data processing module, and wireless transmission module. Ullah et al. (2023)'s study examines the relationship between trade openness, industrialization, and marine pollution using time series data from 1995-2022. Findings suggest that trade openness and industrialization significantly positively affect marine pollution, as trade activities and industrialization lead to large inputs. Sharma et al. (2024) explore the environmental toxicity of oil, and its impact on aquatic ecosystems, soil, and plant life, and suggest strategies to mitigate pollution and reduce its ecological footprint. They also explore the use of aquatic plants as oil sorbents.

Filyos Valley Project

The increasing number of national oil companies has been driven by the fact that, in addition to the direct transfer of profits from energy sales and taxes to the government, they have an active role in achieving certain political objectives in terms of security of supply and industrial competition. Thus, states can be less affected by external factors such as international embargoes and sudden price increases. Accordingly, Türkiye established the Turkish Petroleum Corporation (TPAO) in 1954 to carry out hydrocarbon exploration, extraction, refining, and marketing activities on behalf of the public. In recent years, TPAO has increased its investments in the Sakarya gas field in the Black Sea and has been carrying out activities to reduce Türkiye's dependence on foreign oil and natural gas. Sakarya Gas Field, 170 km away from Filyos within the borders of Zonguldak province (Figure 5), where the natural gas discovered in the Black Sea will be brought to land within the scope of the Sakarya Gas Field Development Project carried out by Türkiye's national energy company, Turkish Petroleum Corporation (TPAO), is located in the Exclusive Economic Zone of the Republic of Türkiye (Turan and Çelikoğlu, 2023).

Türkiye has an enormous geostrategic position as it connects the energy-rich Caucasus, Central Asia, and the Middle East with energy-poor Europe. Moreover, Türkiye aims to become an "energy bridge" as it acts as a bridge between Asia and Europe in the growing East-West trade, especially with the Belt and Road Initiative announced by China in 2013. Located on the historical Silk Road, Türkiye can thus have a central place in both trade of goods and energy transfer. For this purpose, Türkiye initiated the Filyos Valley Project in 2014 in the region where the Filyos River flows into the sea in the east of Zonguldak province in the Black Sea and close to the Sakarya Gas Field (Figure 5) (BAKKA, 2018; BAKKA, 2020)

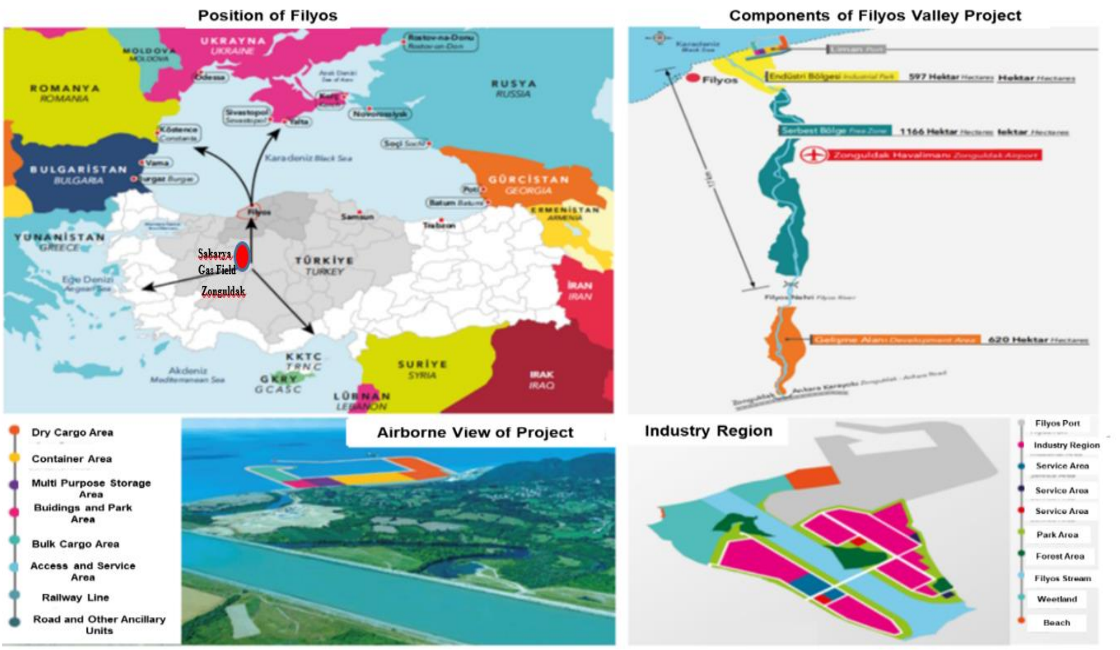

Fig. 5. Filyos Valley Project (BAKKA, 2020)

Within the scope of the Project, which was created in the region directly close to energy resources and the Central Asian Corridor, the construction of the port and pre-fill area, port warehouse area, shipyard, thermal power plant, cement and soil industry, iron and steel plant, industrial zone, LPG storage, petrochemical, petroleum and petroleum products storage facilities and other facilities were planned (Çetinkaya, 2012). The natural gas discovered in the Sakarya Gas Field in the Black Sea will be converted into production here so that Filyos Port, and the expanded industrial zone allocated on the land behind it will have direct access to a natural gas supply (Turan and Çelikoğlu, 2023).

Filyos Port

As energy is determined as a valuable commodity in the free market, Türkiye, which will want to make more use of the energy it has discovered, will need international cooperation that can contribute to regional cooperation, trade, and trust (Bozkus, 2018). If Türkiye overcomes the energy security problem, it will focus more on trade opportunities in the region with its increasing competitiveness, increasing the importance of large capacity ports such as Filyos Port.

The port has a large hinterland area and the national and international trade of the country, especially the Black Sea Basin and Eastern European countries, will be provided through Filyos Port and complements the investments coming to the region along with the free zone and industrial zone investments. It is designed to handle container, bulk, solid-liquid, and ore cargoes. It will include the necessary port facilities. The Filyos port plays a vital role in a broader industrial initiative aimed at fostering the growth of the region. With a depth of 14-19 meters and a berth of 3,000 meters, this port will have the capacity to handle an 800,000-TEU container terminal per year. The Filyos project will consist of a port, a 5,970-hectare industrial park with a 215-hectare mixed industrial zone, a 1,166-hectare Free Trade Zone, and a 620-hectare zoned area that is readily available for use if necessary (Gonca, 2020; Çetinkaya, 2012).

More than 50 ships are working within the scope of the project, although it varies depending on the characteristics of the work carried out within the scope of the Sakarya Gas Field Development Project. A total of 16 of these, including 4 drilling ships, 2 seismic research ships, and 10 support ships, are in TPAO's inventory. The remaining approximately 50 ships, the number of which varies depending on the status of the operations, are used in project activities by procuring services within the subcontracting system. A large port was needed to supply the national fleet and other support ships operating within the scope of the Sakarya Gas Field Development Project. For this reason, Filyos Port, which has not yet started commercial activities, has been a decisive factor in the operation of this project, which will play a critical role in Türkiye's energy security, by TPAO subsidiary TP-OTC. A temporary Coastal Logistics Center has been established to carry out the activities here. In Figure 6, it can be seen that TPAO's drilling and support ships at Filyos Port. Even the port, which has a large capacity for cargo handling, can only respond to the logistics mobility within the scope of the project, especially since drilling ships close the single dock when they dock at the port (Turan and Çelikoğlu, 2023).

Fig. 6. Filyos Port and TPAO Ships (Turan and Çelikoğlu, 2023).

It is essential for such a port, which is of vital importance for Türkiye's energy supply security, to be cautious against many factors, especially against marine pollution that will significantly disrupt operational capability.

In cases of marine oil pollution caused by accidents or illegal discharges from ships, the impacted areas can be categorized into three main groups: marine and coastal ecosystems, the socio-economic structure, and the maritime transportation sector. Among these factors, the socio-economic structure stands out prominently and generates the strongest public reaction. If oil contamination is limited to the sea, the influence on the socio-economic system will be more restricted. Nevertheless, if oil pollution threatens to reach the coastline, its influence on social life intensifies dramatically, resulting in substantial and enduring suffering across other sectors beyond the ones already described (Kıraç et al., 2022).

Oil Pollution and the Behavior of Oil in the Marine Environment

Oil pollution harms the marine-coastal ecosystem and its species, as well as all sectors and individuals that use the coastlines and the seas. Ports and terminals, which are essential for the operation of the maritime industry, are especially vulnerable to the harmful impacts of marine oil contamination. If oil pollution reaches the coastline, there is a substantial possibility of port operations being disrupted, potentially causing delays or even a complete cessation of activities. Several global examples clearly show the effects of oil pollution on social and economic activities (Usluer yet al., 2022). Coastal oil contamination specifically has a substantial adverse effect on both social well-being and financial stability in coastal areas. There is ample evidence to support the fact that ship accidents causing marine pollution have caused substantial disturbance to the socio-economic framework in many nations, namely in Europe, where occurrences have taken place in France and Spain. The above-described occurrences have led to a substantial economic burden, with the expenses for cleaning up and compensating reaching billions of euros. These expenditures include charges associated with the socio-economic effects and the remediation of marine coastal areas (Safety4Sea, 2018). Hence, ports must implement proactive steps to mitigate the risk of marine oil pollution before it intensifies into a critical situation. Within this particular framework, it is important to carry out risk assessments and pollution simulations in conjunction with various scenarios. Subsequently, contingency plans should be established, taking into account the results of these assessments. Contingency plans should be established for a specific facility, such as a container terminal, which would involve incorporating local groups and resources, along with progressive strategies for handling spills of increasing severity. Contingency plans may consist of area-specific action plans, operational procedures for managing and remedying spills, an inventory or database of available equipment, supplies, and resources, scenarios for common spills, and decision trees for specific response actions like employing chemical treating agents or in-situ burning (Fingas, 2014).

Oil spills, whether on water or land, undergo several transformation processes known as the "behavior" of the oil. Weathering refers to a sequence of processes in which the physical and chemical characteristics of the oil undergo alterations following a spill. Weathering significantly impacts the transportation of oil in the environment. The effectiveness of these techniques is highly contingent upon the specific characteristics of the spilled oil and the prevailing meteorological conditions during and following the spill. Weathering processes are strongly influenced by temperature and tend to decrease significantly when temperatures are near zero degrees. The components encompassed within weathering are:

Evaporation: Gasoline, a light fuel, totally evaporates over many days at temperatures above freezing, but only a tiny portion of heavier oil evaporates.

Emulsification: Water can permeate oil through many mechanisms. Emulsification is the act of dispersing one liquid into another liquid in the form of small droplets.

Natural dispersion: It is the process by which small droplets of oil are moved from the surface and mixed into the water column due to the effects of waves or turbulence.

Dissolution: During the dissolution process, the water beneath the oil slick absorbs and removes the most soluble components of the oil.

Photooxidation: It is the process in which the sun's radiation induces the combination of oxygen and carbons in an oil slick, resulting in the formation of new compounds that can resemble resins.

Sedimentation: It is the phenomenon through which oil settles and accumulates at the seabed or in other bodies of water.

Biodegratation: Many bacteria can break down petroleum hydrocarbons. Several types of bacteria, fungi, and yeasts utilize petroleum hydrocarbons as a source of dietary energy (Fingas, 2014).

Following an oil spill over water, the oil possesses a tendency to disperse and form a thin layer on the surface of the water, commonly referred to as a slick. Oil exhibits horizontal dispersion across the sea surface, even in the absence of wind and water currents. The spreading phenomenon is a result of the gravitational force and the interfacial tension between oil and water. Oil slicks on water are propelled across the sea surface by surface currents and winds, in addition to their inherent inclination to disperse. The slick typically travels at a pace equivalent to the surface current and around 3% of the wind speed. If the wind speed exceeds approximately 20 km/h and the slick is located in the open sea, the movement of the slick is mostly influenced by the wind (Fingas, 2014). For the majority of instances, it is necessary to take into account both the wind and surface current.

Timely and efficient action taken in response to oil spills will lead to reduced environmental harm. While prioritizing strategies to prevent oil spills is crucial, it is equally imperative to promptly and efficiently adopt measures for controlling and cleaning up such incidents. Implementing a comprehensive system of contingency planning and response alternatives can expedite and enhance the response to an oil spill, leading to a substantial reduction in both the environmental consequences and the impact of the spill. The oil that is spilled onto the water is rarely fully contained and collected, resulting in a portion of it eventually reaching the shore. Cleaning shoreline areas is a more arduous and time-consuming task compared to conducting containment and recovery operations at sea. Physically extracting oil from certain types of shorelines can potentially cause greater ecological and physical harm compared to allowing natural processes to handle oil removal. Hence, it is imperative to take action to mitigate oil spills at sea before they arrive at the coastline.

Potential Incident Simulation and Evaluation System – PISCES

PISCES is a dedicated simulator utilized for marine incident response. The objective of this system is to create and execute exercises, both in virtual and real-life environments. The purpose of the tool is to streamline training simulations that primarily focus on the reaction to search and rescue operations, particularly those related to oil pollution disasters. Therefore, the mathematical model of the application was created by considering not only environmental factors such as the coastal area, sea surface currents, weather, sea conditions, ice conditions, and ecologically sensitive areas but also human intervention activities. The tool utilizes data from vector-based sea charts to automatically produce closed polygons that accurately reflect the shoreline. The surface current area is created by extrapolating a pre-existing fundamental current vector over a period of time. The surface current velocity at a certain place in the field is determined using linear interpolation of base vector values on a triangle meshed based on the Delaunay principle. A Delaunay triangulation, also known as a Delone triangulation, is a method in computational geometry that separates the convex hull of a set of points in the plane into triangles. These triangles have circumcircles that do not include any of the points. This strategy optimizes the magnitude of the smallest angle in any of the triangles and helps to prevent the occurrence of sliver triangles (Delaunay, 1934).

Ecologically sensitive regions are depicted as polygons consisting of a defined number of clusters. In oil spreading modeling, the Lagrangian approach is used to mimic the movement of many particles that represent the oil layer. These particles are influenced by a combination of wind, current, and diffusion (Delgado et al., 2006). Lagrangian mechanics is a branch of physics that is based on the principle of least action, which states that the path taken by a system between two points is the one that minimizes the action. It is a formulation of classical mechanics. The concept was first presented by Joseph-Louis Lagrange, an Italian-French mathematician and astronomer, during his lecture to the Turin Academy of Science in 1760 (Fraser, 1983).

PISCES is a specialized simulator designed to assist in the organization and execution of command center exercises and area drills that concentrate on responding to oil spills. The system possesses the capability to establish connectivity with crucial resources, including ship-management simulators that encompass Vessel Traffic Service, Search and Rescue modules, communication stations, engine room, and cargo handling simulators. Furthermore, the PISCES simulator is furnished with functional stations that are specifically tailored for civil protection organizations, such as port authorities, marine police, navy, and environmental agencies. This simulator functions as both an instructional instrument and tangible assistance in the event of an oil spill (Perkovic and Sitkov, 2008).

Material and methods

The study prioritizes the accuracy of data input, data processing, and the production of tangible and meaningful outputs, as it is conducted in an actual geographical region with prevailing oceanographic and atmospheric conditions. The PISCES-II simulator is employed to illustrate the extent of scenario-based oil spills, which is the most suitable asset for the study's objective, due to the diverse range of output information it offers. It generates a simulation of oil spread, the rate of evaporation, the dispersion of oil, the burn-off volume, and the pollutant's interaction with the shoreline in the vicinity from a pollution perspective.

When evaluating the extent of an oil spill using modeling techniques, surface currents are the most crucial parameters for achieving accurate simulations. While wind characteristics are vital, they are of secondary relevance in obtaining useful results. According to Fingas (2014), wind-related factors have an impact on only 3% of the oil spread's direction, whereas surface currents have a much greater influence of 97% on the spill's orientation. From this viewpoint, this work utilized the existing surface current modeling integrated within the PISCES-II simulator as the foundation. However, the simulation also incorporates external input. Gürbüz (2010)'s study consolidates statistical data acquired from the Turkish State Meteorological Service (TSMS) for modeling the incident site surface current scheme. These endeavors facilitated the research in ascertaining the surface current in the specific location of the simulated accident at coordinates 41°50’ N-031°50’ E. The data indicates that in the accident area, which can be specifically identified as the region located 20 nm northwest of Filyos Port, the surface current exhibits a south-to-southeast set and drift with a velocity of 0.9 knots (kts).

The initial data set for the PISCES II simulator is received from the Turkish State Meteorology Service (TSMS) and includes monthly mean values for weather temperature, sea surface temperature, and wind parameters. Based on the provided data, the wind patterns that prevail in the western Black Sea during December come from the north-northeast at a speed of 20 knots. The average air temperature is 8 °C, while the average seawater temperature is 9 °C (Doğan et al., 1996-1998; Çakıroğlu et al., 2017; Bayırhan and Gazioğlu, 2020; TSMS, 2024). The objective of this study is to simulate the outcomes of the most severe possible situation, where the initial inputs are chosen to represent conditions that could cause the most amount of damage. Therefore, the wind direction for the simulation scenario is selected to be from the northeast, which aligns with the predominant winds in the area. The study employed a sample technique to simulate a 15-hour oil spill scenario, involving the spread of 2600 tons of oil. The initial variables utilized for the PISCES-II simulation are displayed in Table 1.

In this context, in the following sections of the study, the behavioral patterns of oil pollution that may occur in the Black Sea due to the increasing sea traffic in the east-west axis will be revealed within the determined oceanographic and meteorological conditions. Subsequently, the duration of this pollution's impact on the Filyos port, which is situated close to the Istanbul Strait, the convergency zone of the sea traffic, will be determined.

Table 1. PISCES-II Simulation Initial Conditions.

Position	Oil Type	Wind/ Current	Oil spill amount	Air temp.	Water temp.	Wave height	Water density
41°50' N 031°50' E	KOLE MARINE, AMACO Group III Viscosity: 8.59 cSt Surface Tension: 25.6 dyn/cm Density: 0.85 g/cm^3	N-NE 20 kts / S-SE 0.9 kt	Initial point source spill: 2000 m^3 Leak source spill: 60 m^3/h (10 hrs)	8 °C	9 °C	0.3 mt.	1010 kg/m^3

Results

This section mostly discusses an incident that took place northwest of the Filyos Port, namely at coordinates 41°50' N-031°50' E. The incident occurred roughly 20 nautical miles from the port. At first, there was the discharge of 2,000 tons of crude oil, followed by a continuous flow of 60 tons per hour, resulting in a final total of 2,600 tons of oil being discharged into the sea. The outlined scenario explains how the relevant meteorological and oceanic conditions enabled the oil spill to spread to the port. The PISCES decision support system is used to simulate the situation, demonstrating the spread of oil in the water and the duration it took to reach the port. This information is visually represented in Figures 7-10.

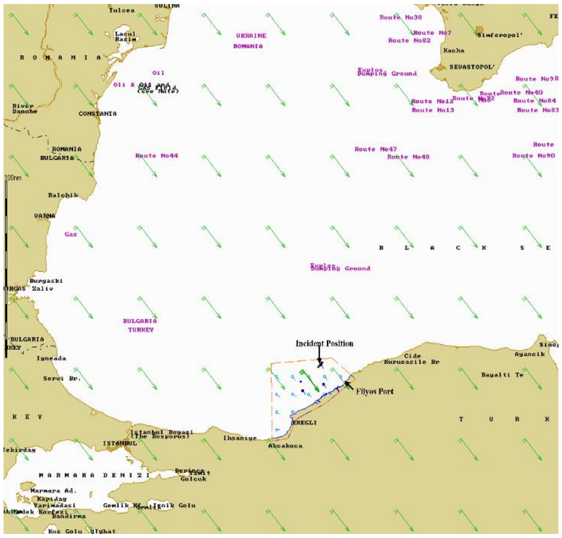

Fig. 7. Initial position of pollution.

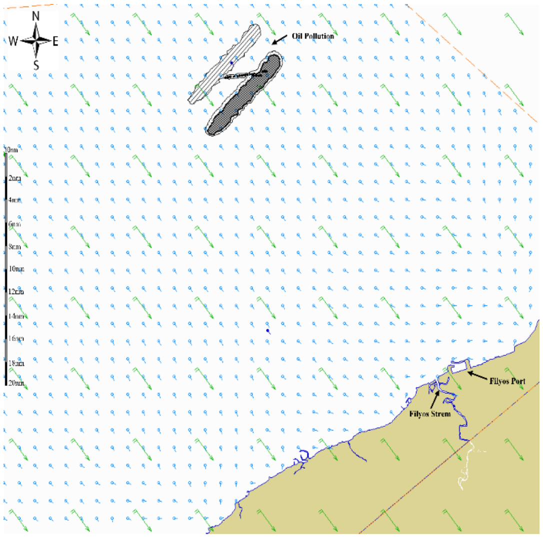

Fig. 8. Spreading of oil after 1 hour.

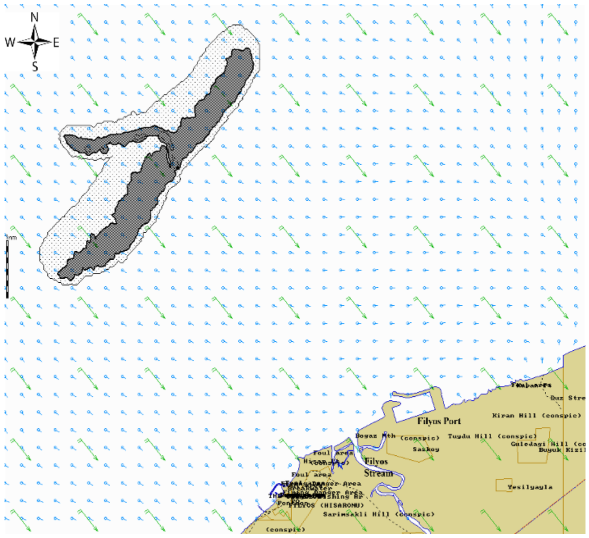

Fig. 9. Spreading of oil after 7 hours.

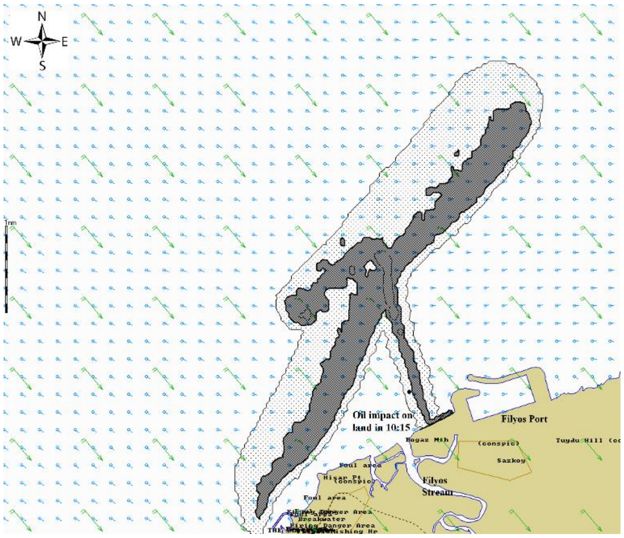

Fig. 10. Spreading of oil after 11 hours.

It has been determined that the oil pollution that occurred at the incident location was stranded on the coast for 10 hours and 15 minutes which has been illustrated in Figure 10. The situation of the pollution 13 hours after the incident is shown in Figure 11 while 15th hour situation is shown in Figure 12.

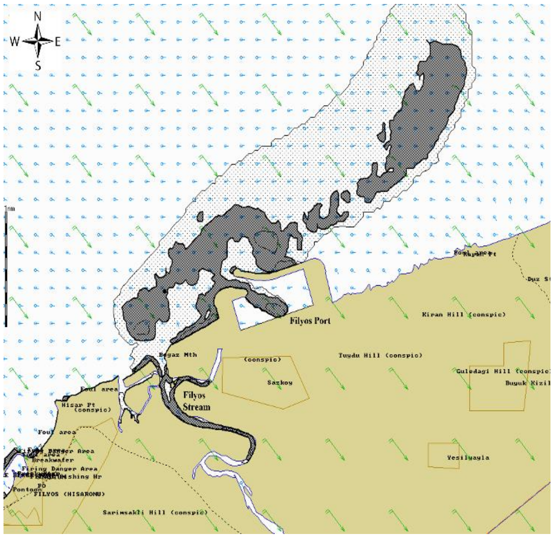

Fig. 11. Spreading of oil after 13 hours.

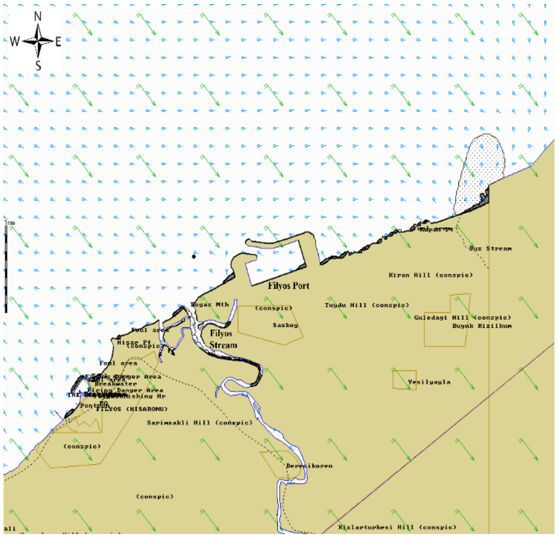

Fig. 12. Spreading of oil after 15 hours.

As observed in Figure 11, oil pollution reached the entrance of Filyos Port around the 13th hour and, driven by regional surface current formations and wind effects, penetrated the port itself, further contaminating the Filyos River located immediately to the west of the port. This scenario implies a significant restriction in the operational capabilities of the vessels within the port due to the entrance being covered with pollutants. The parameters of the behavior patterns of the oil pollution for 15 hours are shown in Table 2 and Figure 13.

Table 2. Behaviors of oil pollution for 15 hours.

Time	Amount spilled, t	Amount floating, t	Amount evaporated, t	Amount dispersed, t	Max thickness, mm	Slick area, km²	Viscosity, cSt
0:00	0	0	0	0	0	0	
1:00	2060	856	171	1033	0.9	14.6	106
7:00	2420	727	337	1354	3.2	23.1	611
11:00	2600	784	396	1418	8.4	20.9	790
13:00	2600	762	410	1421	77.1	14.2	865
15:00	2600	753	414	1422	271	1.6	884

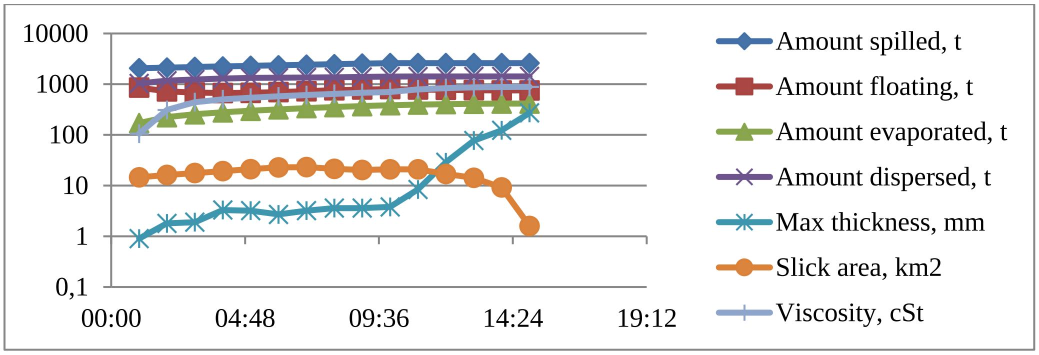

Fig. 13. Diagram of oil behaviors during 15 hours.

When Table 2 and Figure 13 are examined, it is determined that within 15 hours after pollution, 414 tons of spilled oil evaporated, the thickness of the oil on the water surface reached a maximum of 271 mm, while 1423 tons dispersed. The dispersion of the oil from the sea surface started in the first hour after the spillage. Due to the seasonal conditions resulting in low air and seawater temperatures, combined with north-northeast winds spreading the oil molecules over a wide sea area to the south, an increased incorporation of water molecules into the oil facilitated its rapid dispersion into the water column. High wind speed and sea state, as an output of seasonal conditions, contributed to the dispersion of oil onto the sea surface.

In light of the findings obtained from the PISCES scenario, it seems necessary to use barriers to divert the pollution to a different area offshore before the oil interacts with the shore around the 10th hour. Additionally, securing the entrance of Filyos Port and the Filyos River Delta with barriers is necessary.

Conclusion

The Filyos Valley Project is an integrated initiative encompassing the Filyos Free Zone, Filyos Industrial Zone, and Filyos Port Project, along with other industrial areas, storage areas, non-residential urban workspaces, and various flood protection structures. Such a large and significant project naturally assumes the role of a key driver for regional development. Upon completion of all its components, the Filyos Valley Project will contribute to the regional economy, transforming the area into a major trade center and logistics hub. Within the scope of this project, one of Türkiye’s largest ports is constructed at the Filyos River Delta. Filyos Port is strategically positioned close to the approach routes of the Istanbul Strait, acting as a contingency zone for east-west maritime traffic in the Black Sea, facilitating the delivery of Central Asian oil to demand points.

Filyos Port, which is aimed to have an important share in Turkey's maritime business management, will contribute to Turkey's inland region economic development on the North-South axis thanks to its hinterland connections, as well as its potential to be a hub-port between the East-West trade routes. The central port role that Filyos Port is expected to play, both in the collection and processing of the Black Sea natural gas resources and in the handling of other maritime transportation cargoes, is increasingly capturing the attention of stakeholders in maritime business management.

This study presents a scenario to determine the potential impact duration of an oil spill in the Western Black Sea on the Filyos Port, which promises significant socio-economic prospects. It was determined that under winter conditions, an oil spill occurring approximately 20 nautical miles from the port could pollute the entrance of Filyos Port and the Filyos River Delta within approximately 10-13 hours.

Prevailing winds in the Western Black Sea generally come from the North-Northeast direction. Consequently, any marine pollution originating from vessels located west of the 032°E longitude, near the approach routes of the Istanbul Strait, is highly likely to disrupt the operational capabilities of Filyos Port and contaminate the ecologically sensitive Filyos River Delta. Following the pollution interacting with the port entrance, the entry and exit of TPAO drilling and support vessels currently using the port as a mother port will be obstructed, significantly disrupting other port services. When considering the port entrance along with the Filyos River Delta, such pollution could result in the suspension of operational activities at the port, substantial economic losses, and a major environmental disaster.

Therefore, contingency plans should be formulated, specifying the types of intervention equipment to be used, directions for diverting and collecting the oil at sea surface before it reaches Filyos Port, immediate evacuation of ships from the port upon pollution reporting, and designation of an alternative port as a shelter. To this end, port authorities should diversify the scenario developed in this study according to all seasonal conditions and identify oil dispersion patterns. Following the identification of this, marine pollution intervention strategies should be established.

Declaration of competing interest

The author declares that there are not any competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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