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Monitoring of hydrocarbon pollution in the Black Sea and the Sea of Azov using remote sensing methods

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SUMMARY

Sentinel-1 images of the Black and Azov Seas from 2024 to 2025 were analyzed for hydrocarbon pollution. An accident that caused a fuel oil spill in the Black Sea near the Kerch Strait occurred on December 15, 2024, when two Russian tankers, "Volgoneft-212" and "Volgoneft-239," were damaged, resulting in approximately 4,000 tons of fuel oil entering the Black Sea. However, the exact amount of hydrocarbon spilled is unknown. The authors used a methodology for determining the affected area, the length of the polluted coastline, and the minimum and maximum widths of the hydrocarbon contamination zones in the Black and Azov Seas and their coastal areas. To process Sentinel-1 satellite images, the authors used the publicly available Copernicus browser service. A total of 24 Sentinel-1 images from December 18, 2024, to February 18, 2025, were analyzed.

Introduction

Pollution of the world's oceanic waters with oil and petroleum products is one of the global environmental problems and has already reached about 1/5 of its area *(Puzanov & Badzhanova, 2022)*. The volume of this pollution is estimated at 5-10 million tons annually *(Bilokopytov & Mitskevych, 2013)*. Its causes include emissions from ships and the aftermath of accidents, while the consequences pose a threat to marine and coastal ecosystems. This issue in the Black Sea worsened after the accident in November 2007 in the Kerch Strait area, when several ships were involved in accidents because of a severe storm, sailors died or went missing, and fuel oil, diesel fuel, and sulfur were spilled into the sea *(Prytula, 2008)*. Pollution zones of the seas have been identified by the authors *(Belobrova et al., 2009; Chetverikov et al., 2019)* using various methods based on satellite images, and the thickness of the hydrocarbon stain was determined based on aerial photography data.
The authors have proposed to analyze the pollution of the Black and Azov Seas with fuel oil following the destruction of two Russian tankers, "Volgoneft-212" and "Volgoneft-239," on December 15, 2024, near the Kerch Strait area, when more than 4 thousand tons of fuel oil were spilled into the sea *(Zhuravel', 2024)*. However, the exact volume of pollution is unknown *(Gerasimova, 2025)*.

Method

The determination of the areas polluted with hydrocarbon products in the Black and Azov Seas and the coastal zone was carried out using the publicly available Copernicus browser service *(The Copernicus Data Space Ecosystem Browser, n.d.)*. To analyze the dynamics of pollution in the Black and Azov Seas, radar satellite images from the Sentinel-1 satellite were used for the period from December 18, 2024, to February 18, 2025. Radar images depict texture and allow for the visual interpretation of hydrocarbon stains on the sea surface. Hydrocarbon products in the sea form a film and are reflected in radar images as dark pixels. To process the images, specifically for visual interpretation, the determination of the area of continuous hydrocarbon stain patches, the length of the polluted coastline, the distance from the patches to the coastline, the width of the hydrocarbon strip, and others, several publicly available features of the Copernicus browser service were used: measure – for measuring distances between objects and determining areas, draw a line – for defining the perimeter, and more.

Results

The tanker accident occurred on December 15, 2024, near Kerch Strait. As of December 18, 2024 (Figure 1), the fuel oil stain covered an area of 3.96 km², located 29.9 km from the city of Kerch.

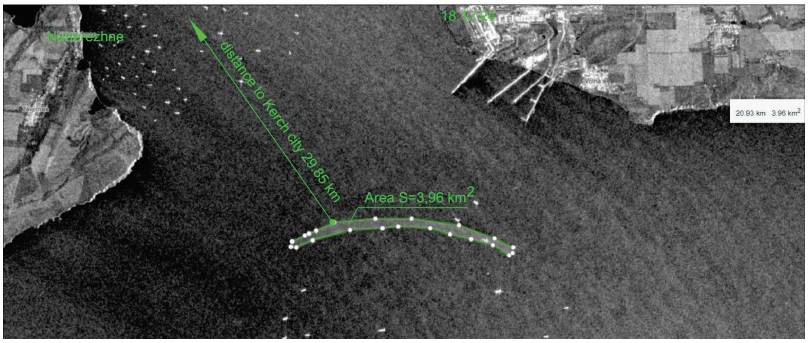


Figure 1 *Pollution near Kerch (Sentinel-1 satellite image from December 18, 2024)*

As of December 19, 2024, the fuel oil stain with an area of 74.6 km², located 16.4 km from Anapa, is moving towards the Taman Peninsula (Figure 2). As of January 5, 2025, the hydrocarbon polluted has reached the Sevastopol coastline, with fuel oil point accumulations covering an area of 1912.5 km², the

length of the polluted coastline is 104.2 km, and the width of the polluted belt ranges from 3.4 km to 36.3 km (Figure 3).

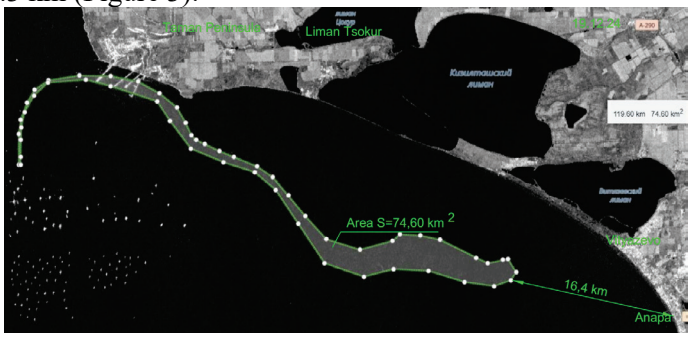


Figure 2 *Pollution near Anapa (Sentinel-1 from December 19, 2024)*

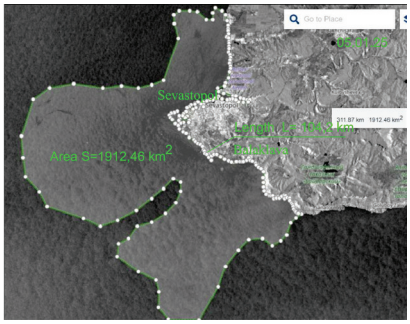
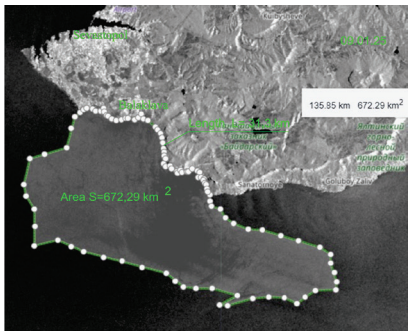


Figure 3 *Pollution of Sevastopol (Sentinel-1 from January 5, 2025)*

In the Sentinel-1 image from December 23, 2024, the area of the hydrocarbon stain near Kerch was 167.0 km², with the length of the polluted coastline being 57.1 km, and the width of the pollution belt ranging from 0.8 km to 10.9 km. As of December 30, 2024, two fuel oil stains, covering 3.35 km² and 3.45 km², were observed at distances of 68.3 km and 87.2 km from Kerch, respectively. As of December 31, 2024, hydrocarbon point accumulations near the coast of Feodosia covered 3493.05 km², with the polluted coastline stretching 156.5 km. The width of the polluted belt ranged from 48.9 km to 1.6 km. As of January 4, 2025, the coastline from Sudak to Yalta was polluted over a stretch of 102 km, with hydrocarbon point accumulations covering an area of 621.1 km² and the width of the polluted belt ranging from 0.8 km to 13.2 km.

The fuel oil stain continues to move along the Crimean Peninsula coast. As of January 9, 2025, the fuel oil stain observed in the image from January 5, 2025, had split (Figure 4): the first hydrocarbon point accumulations near the coast of Sevastopol covered 672.3 km², the coastline was polluted over 31.3 km, and the width of the polluted belt ranged from 0.7 km to 17.1 km, with movement observed towards the east (Figure 4, a); the second fuel oil stain – 77.03 km², length of the polluted coastline of the Yalta district from the village of Gurzuf to the village of Kurpaty was 28.5 km, and the width of the polluted belt ranged from 0.4 km to 4.96 km (Figure 4, b).

a



b

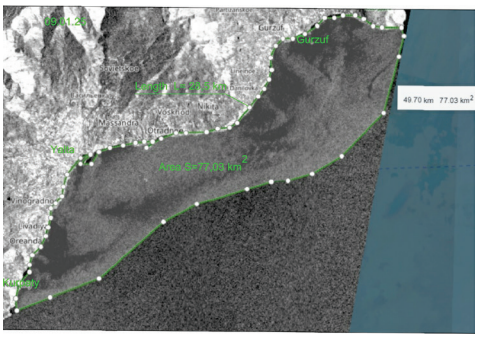


Figure 4 *Sentinel-1 satellite image of the Crimean Peninsula from January 9, 2025*

As of January 13, 2025 (Figure 5), hydrocarbon stains are approaching the coast of Georgia: the first hydrocarbon point accumulations (Figure 5, a) is located 36.1 km from Batumi, covering an area of 343.92 km², the second (Figure 5, b) – covers 602 km² and is located less than 500 meters from Batumi. Additionally, the coastline from Batumi to Shekvetili, a stretch of 41.3 km, is polluted, with the width of the polluted belt ranging from 6.2 km to 40.0 km.

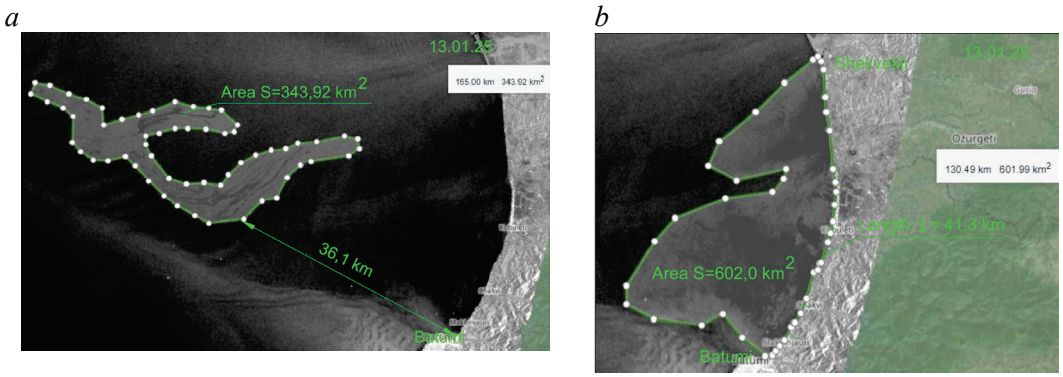


Figure 5 *Hydrocarbon near the coast of Georgia (Sentinel-1 satellite image from January 13, 2025).*

As of January, 11 and 16, 2025, in the Sea of Azov, the hydrocarbon point accumulations of 186.9 km² near Berdyansk was observed, with the polluted coastline extending 54.1 km. The width of the pollution belt ranged from 3.6 km to 204.0 m. As of January 24, 2025, near Henichesk and Kyrylivka, the hydrocarbon points accumulations covered an area of 5834.75 km², with the polluted coastline stretching 231.3 km, and the width of the polluted belt ranging from 7.4 km to 93.1 km.

As of January 27, 2025, the hydrocarbon point accumulations were observed near the Turkish coastline, with hydrocarbon covering the coastline from Sile to Babalı. The area of the hydrocarbon points accumulations 8967.2 km², with a polluted coastline of 91.8 km, and the width of the polluted belt ranging from 18.6 km to 148.7 km.

As of February 6, 2025, signs of hydrocarbon pollution covering 83.9 km² were observed in the Black Sea waters near the coast of Georgia, 47.0 km from Poti (Figure 6). The area of hydrocarbon point accumulations was 819.8 km², with a polluted coastline of 55.8 km. As of February 7, 2025, hydrocarbon points accumulations covering 6905.4 km² were located 10.9 km from Gagra.

As of February 17, 2025, two hydrocarbon points accumulations were observed: near Berdyansk (289.8 km², with a polluted coastline of 52.3 km) and near Naberezhne (200.3 km², with a polluted coastline of Obytichna Kosa, 48.8 km) (Figure 7).

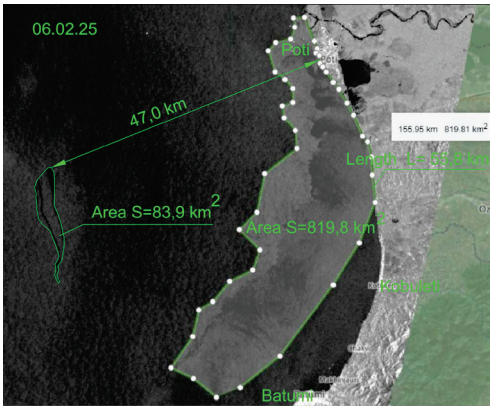


Figure 6 *Hydrocarbon near the coast of Georgia (Sentinel-1 satellite image from February 6, 2025)*

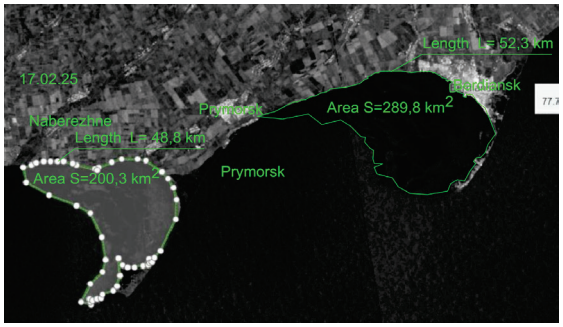


Figure 7 *Coastal pollution near Berdyansk and Obytichna Kosa (Sentinel-1 satellite image from February 17, 2025)*

As of the publication date, the coastal pollution of the Black and Azov Seas is: the coastline of the Autonomous Republic of Crimea – 420 km, Turkey – 188.5 km, Georgia – 97.1 km. In the Sea of Azov,

the extent of coastal pollution is increasing, and as of February 18, 2025, it amounts to 756.5 km. The largest accumulation of hydrocarbon signs is observed in the Sea of Azov along the coast of Berdyansk, Obytichna Kosa and Mariupol are more than 100 km.

Conclusions

The methodology for monitoring hydrocarbon pollution in the waters of the Black and Azov Seas using the Copernicus browser service has been further developed. An analysis of Sentinel-1 satellite images for this region was conducted from December 18, 2024, to February 18, 2025. The methodology includes the analysis of the dynamics of hydrocarbon stains movement, the determination of the areas of hydrocarbon points accumulations in the seas, and the length of the polluted coastline. We believe this methodology is effective and can be used as a source of information for a preliminary assessment of environmental damage, the scale, and consequences of technological disasters caused by hydrocarbon product spills into the waters of the World Ocean. The obtained results of pollution in the marine waters and coastal zones can be used for planning measures to protect Ukraine's natural environment and determining the volume of compensation for damages caused to ecosystems.

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