The Role of Remote Sensing to Detect Oil Pollution in Istanbul Strait, Turkey

Tugsan ISIACIK COLAK

Istanbul Technical University Faculty of Maritime, Tuzla 34940, Turkey Istanbul

isiacik@itu.edu.tr

ABSTRACT

Being an important economic area for oil transportation, Black Sea has a heavy tanker traffic on one of the major tanker shipping routes of the world which flows from Black Sea to Open Seas. The only connection to Black Sea is Istanbul Strait which is the narrowest one of the world. Istanbul Strait has a high risk of ship accidents especially tanker accidents due to the difficulties of navigation at dense traffic and narrow sea area. Any tanker accident at Istanbul Strait may result tragic and serious problems regarding marine environment and endanger lives of almost 12 million people, as happened after M/T Nassia accident in the past. Remote sensing data and techniques play an important role to combat and to detect oil pollution from satellite and aerial observations. In an emergency case of any oil pollution disaster, it is possible to detect the spatial distribution and size of oil pollution using remotely sensed data. Based on information created from Near Real Time satellite images, it is possible to generate an emergency contingency plan rapidly and support recovery actions.

This paper examines the role of remote sensing techniques to detect and combat oil spills, to minimize their impact and to mitigate oil pollution in case of an accident in Istanbul Strait.

Keywords: oil pollution, remote sensing, contingency plan

1. INTRODUCTION

Major Shipping Routes which are called as Global Oil Choke points have potential oil pollution threats due to crude oil tanker traffic (1). One of the choke point is Turkish Straits, (Çanakkale Strait-Marmara Sea and Istanbul Strait). Turkish Strait System is the only maritime access route between Black Sea and Mediterranean (2). All crude oil shipped by sea out of the Black Sea has to pass through the Turkish Straits to reach the world market. Because of Turkey's position as a transit country between the oil exporting and importing countries, there is a high vessel traffic in the Turkish Straits (3). Turkey has experienced many marine accidents resulting in oil spills and there is always potential risk for a major oil spill especially in the Istanbul Strait. The Istanbul Strait is about 18 nautical miles in length and just 700 meters wide at the narrowest point. It contains several significant turns, which can serve to obscure oncoming traffic, and require course alterations of up to 80 degrees (4). Currents in the Strait may be strong and variable in direction. The general surface current flows from the Black Sea to the Mediterranean at speeds which typically average 2 - 4 knots, but can reach 7 knots in the event of strong northerly winds (4). Turkey has experienced a number of medium to large spills, particularly in the Istanbul strait including Independenta (1979), Jahireguneri (1984), Jambur (1990), Nassia (1994), 'Mystery spill' (1996), Volganeft (1999) and Gotia (2002) (2). It is very important to prevent any accident to avoid oil pollution. But if any oil spill accident generates, we have to take precautions to mitigate oil pollution. Satellite remote sensing is now an accepted and integral component of effective oil spill response (5). This paper examines the role of remote sensing for contingency plan against any oil pollution for the Istanbul Strait.

When oil is spilled into the ocean, the oil undergoes physical and chemical changes such as spreading, drift, mixing, evaporation, sedimentation, dissolution, emulsification, photo oxidation, and biodegradation (6). These changes can be called oil transport and weathering processes. In processing these changes, oil spills can form different pollution types and show different visual characteristics.

Most oil spills are accidental and thus unpredictable. Spills can happen, at any time of day or night, and in any weather condition. Prevention is considered as the most critical area in all jurisdictions, with considerable efforts being placed to ensure the risk of a spill is as low as reasonably possible (7). However, once a spill occurs, the best approach for containing and controlling the spill is to respond quickly following a contingency plan and in a well-organized manner (8). A contingency plan (or management strategy) looks at all the possibilities of what could go wrong and details upon actual events, including the contacts, resource lists, and strategies to assist in the response to the spill (7). A well-designed contingency plan should be easy to follow and usually includes hazard identification, vulnerability analysis, risk assessment and response actions (7). The plan can help minimize potential harm to human health and the environment by ensuring a timely and coordinated response. Well-designed local, regional, and national contingency plans can assist response personnel in their efforts to contain and clean up oil spills by providing information that the response teams will need before, during, and after spills (8). Remote sensing technology is a useful decision support tool for contingency plan to mitigate oil pollution. The appearance of oil spills on water surface (varying thicknesses, color changes, patches, borders) the degree of coverage, the position and time of observation are important factors for oil spill contingency plans to determine the quantities of hydrocarbon spilt using visible observation (9).

2. OIL SPILL REMOTE SENSING

Remote sensing is the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information (10). Remote sensing provides different methods for acquiring information from ocean and seas. There can be many applications for remote sensing, in different fields, but especially (11).

Natural resource management, sustainable development, environmental degradation, and disaster management are most important topics nowadays for remote sensing (12). As a matter of fact big oil spill accidents cause a disaster not only at sea, it affects also coastal environment. Oil spill monitoring, mapping and predicting oil spill extent and drift, strategic support for oil spill emergency response decisions, identification of natural oil areas for exploration are study area of disaster management of oil spill with remote sensing (11). Rate and direction of oil movement can be calculated with multi temporal remote sensing data then entering these data to drift prediction modeling which makes further control and cleanup efforts more effective and easier (13).

2.1 Kinds of Remote Sensing Tools for Oil spill Monitoring

There are different remote sensing applications for detection of oil pollution/spills on sea surface. These include ultraviolet, visible, infrared and microwave wavelength regions of the electromagnetic spectrum. Oil gives different responses and signatures to radiation from different wavelengths. Multispectral and hyperspectral remote sensing (14), thermal infrared (15), synthetic aperture radar (SAR) (16), have different detection principles and imaging characteristics. Therefore, the detected targets of oil spills will be different in each remote sensing image.

2.1.1 Visible Remote Sensing

With the development of optical remote sensors and quantitative remote sensing studies, optical remote sensing technology used in marine oil spill monitoring has been improved (17). Based on the radiance (brightness) of optical remote sensing satellite images or reflectance spectra of in situ measurements, the different oil spill pollution types can be identified (18). Visual characteristics of marine oil spills help to improve the interpretation of optical remote sensing images (16). Optical remote sensing technology to identify those oil pollution types is based on the theory of light absorption, scattering, and reflection. The thickness of the oil slick spectra of background water are very important parameters to interprate oil spill (17).

Optical Sensors include cameras and scanners in the visible, infrared and ultraviolet.Visible sensors are passive sensors that operating in the visible region of the light and are still widely used in oil spill remote sensing (19). Sun-glint, wind sheen, see weeds, darker shore are the limits for visible remote sensing of oil. Visible sensors can not normally operate at night as they are based on the reflectance of sunlight. But the advantages of Visible sensors are that they can easily mounted on aircraft. Visible sensors are less costly and easy to use; therefore, they are often used to create the basic data in coastal areas (17).

2.1.2 Infrared Sensors

Infrared sensors are passive sensors. The oil absorbs solar radiation and emits some part of it as the thermal energy mainly in the thermal infrared region (8-14 μm) (17). Oil has a lower emissivity than water in the thermal infrared region (TIR) and therefore oil has a distinctively different spectral signature in the TIR compared to the background water (20).

TIR is typically used for oil spill detection in the IR region. Thick oil absorbs greater amounts of radiation and as a result it appears hot in TIR. The oil of intermediate thickness appears cool in this region, but thin sheens can not be detected in TIR. The thickness of the minimum detectable layer lies between 20 and 70 μm. The change from hot to cold layer occurs between 50 and 150 μm (17). At night, the reverse behavior is observed: heat loss in oil is faster than in water and therefore, thick oil appears cooler than water (17).

2.1.3 Ultraviolet Sensors

UV scanners capture the ultraviolet radiation reflected by the sea surface. A UV sensor is a passive sensor as it uses reflected sunlight in the ultraviolet region (0.32-0.38 micron) for detecting oil spills (21). Oil has stronger reflectivity than water in the UV region. Even a very thin oil film has a strong reflectance in the UV region. Very thin sheens of thickness (less than 0.1 micron) can be detected using a UV sensor. However, UV sensors cannot detect oil thickness greater than 10 micron (17). UV images can only give information about the relative thickness of the oil slick . False detection may occur due to the wind sheen, sun glint and sea weeds. Interferences in UV are different from IR and a combination of these two techniques can provide improved results for oil spill detection (22). UV images are based on the reflected sunlight and hence cannot operate in the night (21).

2.1.4 Radar

Radar is an active sensor and operates in radio wave region. Radar waves are reflected by capillary waves on the ocean and therefore, a bright image is obtained for ocean water. Oil diminishes capillary waves and as a result, if oil is present in the ocean then reflectance is reduced. Hence, the presence of oil can be detected as dark part in the bright image for the ocean (17). Radar is useful as it can be used to detect oil over a large area (23). Thus, it can be used as a first assessment tool to detect the possible location of an oil spill (21). Radar can work in both inclement weather and at night. SAR (Synthetic Aperture Radar) and SLAR (Side Looking Airborne Radar) are the two most common types of Radar which can be used for oil spill remote sensing. SAR has superior spatial resolution and range than SLAR (24). However, SLAR is less expensive and predominantly used for air borne remote sensing. A SAR has superior spatial resolution and range than SLAR (24).

The most common Radar (microwave) sensor for oil detection on sea surface is the Synthetic Aperture Radar (SAR) (25). SAR image is a measure of surface roughness depending on the backscatter. The main mechanism in detection of oil slicks is the dampening effect of oil on water. Dampening of sea waves results in reduced radar return from the affected area, so that oil slicks appear as relatively dark features on the SAR scenes (26). RADARSAT,

TERRASAR, ALOS, COSMO-SKYMED, ERS-2 SAR and TanDEM X are examples for SAR Satellite. Neither very calm sea nor very rough sea surface is favorable conditions for oil slick detection (24).

3. ISTANBUL STRAIT

The Turkish Straits forms the boundary between the Black Sea and the Mediterranean Sea, and is the only maritime access route between the two. Consequently, all crude oil shipped by sea out of the Black Sea has to pass through the Turkish Straits to reach the world markets. The tanker traffic is very dense through the Straits (2). Especially Istanbul Strait which connects the Sea of Marmara with the Black Sea (25), is an important oil transit chokepoint. Istanbul Strait is not only international oil shipping water way, there is a huge local traffic between two continents, approximately 2 million people. Car ferries, fishing vessels, touristic boats are also making marine traffic worse at Istanbul Strait.

Navigation through Istanbul Strait is not easy especially for big oil crude tankers. Istanbul strait is 31 km long, 1.6 km wide on the average and 0.07 km at the narrowest point, the maximum depth being 110 m. Also during passage of Istanbul Strait very large alterations of course exceeding 45 degree are needed (2). The depth is another risk for big tanker. Another risk for ships is current, current speed can reach 7-8 knot locally. To summarize; local currents, narrow bends, inland traffic are difficulties of Istanbul Strait. Istanbul city population is exceeding 14 million people, in any case of tanker accidents, explosion, fire and oil spill are very high risks. There are a lot of serious accidents through the Istanbul Strait . The worst two accidents are tanker accidents; Nassia and Independanta. Crew members were dead and 95000 ton oil spilled to the sea and burned at 1975 due to collision M/T Independanta and vessel M/V Evriali. At 1994, Tanker Nassia and M/V Shipbroker collided and 20000 tons oil spilled and 29 crew member died (28).

Figure 1: M/T Independanta and M/T Nassia after accident (2)

After serious accidents Turkish Strait Vessels Traffic Service (TSVTS) was established for safety navigation, emergency team service and reducing risks of any accidents. Istanbul Strait is divided into four part and continues monitoring is carried out by Vessel traffic operator. The collection of information on marine environment and vessel traffic areas involves a combination of sensors. Eight remote sensor sites for Istanbul Strait located on (29). The entire TSVTS area is covered by microwave radars and CCTV equipped. Six Automatic Identification Systems base stations were established so the whole identification of ships and their information are being enabled to see by VTS Operators and General Director of Coastal Safety of Salvage Administration of Turkish Government (2). Doppler current sensors, surface water measurement sensors, salinity, temperature profilers, automatic weather and dGPS Reference stations, VHF, MF/HF, Inmarsat –C finder stations and AIS base stations are available for the whole system. Istanbul Strait is monitoring by TVTS System (29).

4. IMPORTANCE OF AERIAL OBSERVATION SYSTEMS AS A DECISION TOOL OF OIL SPILL RESPONSE PLAN FOR ISTANBUL STRAIT

Optical remote sensing with satellite is a good decision tool for oil spill response plan if only the weather condition is non-cloud and day light is sufficient. But it is not guarantee that all oil spill occurs during day light or clear weather. MODIS (Moderate Resolution Imaging Spectroradiometer,)/MERIS (Medium Resolution Imaging Spectrometer) optical satellite system temporal resolution is very high 1-2 day, revisit time is daily. It seems ideal for oil spill monitoring but their spatial resolution is very coarse. 300 km (MERIS) and 250 km (MODIS) at nadir are not ideal to identify or any oil spill through the Istanbul Strait. SAR sensors on satellite sytems (RADARSAT, TERRASAR, ALOS, COSMO-SKYMED, ERS-2 SAR and TanDEM X) temporal resolutions are low make immediate preventing oil spill action plan.

When any tanker oil spill accident occurs in Istanbul, it is a great advantage that; the TSVTS at Istanbul Strait is making real time monitoring, but it should be supported with aerial observation both SAR/SLAR and for day time optical remote sensing systems. Airborne observation sensors are more useful for quick respond of oil-spill accident than satellite systems. Airborne observation should be used in the event of an accident, to assist in recovery and dispersion operations at sea. The aims of the observation missions are to, locate the slicks, accurately describe the slicks, map the pollution in order to monitor the pollution, adjust drift models, guide response operations that day and prepare the response operations for the following days (30). Visible sensors have advantages in terms of having both good spatial resolution and temporal resolution. It is possible to monitoring spillage area. Radar sensors have advantages for providing oil spill affected area. Oil spill monitoring is also necessary when the weather is cloudy or dark for effective surveillance operation. SLAR is the ideal sensor for oil spill.

Measuring oil thickness is the other important concern to calculate the quantity of oil spilled area especially for the shore line. Total volume of the oil calculation is important for the cleaning operation; dispersant application quantity. IR/UV is the best method for oil spill thickness measurement for oil cleaning operations.

5. CONCLUSION

Accidental oil spill is not occasionally taking place but amount of spillage affects will be high. One of the accepted risk area is Istanbul Strait. Because of being an important economic area for oil transportation, Black Sea has a heavy tanker traffic on one of the major tanker shipping routes of the world which flows from Black Sea to Open Seas. The only connection to Black Sea is Istanbul Strait which is the narrowest one of the world. Istanbul Strait has a high risk of ship accidents especially tanker accidents due to the difficulties of navigation at dense traffic, narrow sea area and strong current system It contains several significant turns, which can serve to obscure oncoming traffic, and require course alterations of up to 80 degrees. Most oil spills are accidental and thus unpredictable. Spills can happen, at any time of day or night, and in any weather condition. The worst two accidents are tanker accidents; Nassia and Independanta. Crew members were dead and 95000 ton oil spilled to the sea and burned at 1975 due to collision M/T Independanta and vessel M/V Evriali. At 1994, Tanker Nassia and M/V Shipbroker collided and 20000 tons oil spilled and 29 crew member died. After serious accidents Turkish Strait Vessels Traffic Service (TSVTS) was established for safety navigation, emergency team service and reducing risks of any accidents. These system is working continuously and making real time monitoring. Eight remote sensor sites for Istanbul Strait located on. TSVTS area is covered by microwave radars and CCTV equipped. Six Automatic Identification Systems base stations were established so the whole identification of ships and their information are being enabled to see by VTS Operators and General Director of Coastal Safety of Salvage Administration of Turkish Government. Some seawater parameters are also measured salinity, temperature and current by sensors. According to international regulations a national contingency plan is required to take response action for oil spill according to level of oil spill.

Remote Sensing helps to oil spill disaster management. It is a good decision tool when locating oil spill on map. Collecting and processing data should be as fast as possible because time is very important for oil spill surveillance. For quick respond aerial observation systems should be preferred.

For Istanbul Strait, aerial observation monitoring should be used. It is clear that no signal sensor is the best. Every sensor provides effective aim for oil spill surveillance operation. Multisensor system (visible-IR/UV-Microwave) is the best as described in the previous section. Integration of TSVTS, AIS and an aerial observation tool with multisensor system is the solution of the real time monitoring of Istanbul Strait.

REFERENCES

1. World Oil Transit Chokepoints, US Energy Information Administration, November 2014.

2. Oral. N., Ozturk, B., The Turkish Straits Maritime Safety, Legal Aspects, Turkish Marine Research Foundation Publication no:25, ISPN -975-8825-15-1, Istanbul, 2006

3. Turan, M., Turkey's Oil Spill Response Policy: Influences and Implementation, The United Nations-Nippon Foundation Fellowship Programme 2008 – 2009, Division For Ocean Affairs and The Law of The Sea Office Of Legal Affairs, The United Nations New York, Boston,2009

4. Briefing Paper for OCIMF Member Companies Guidelines for Transiting the Turkish Straits, August 2007

5. Partington K. An Assessment of Surface Surveillance Capabilities for Oil Spill Response using Satellite Remote Sensing Provided for IPIECA and OGP, PIL-4000-35-TR-1.2, April 2014

6. Xie, H., Poojitha D., Nakata, K., Modeling Emulsification After an Oil Spill in the Sea, Journal of Marine Systems 68 (2007) 489–506, 2007

7. Chen, B., Zhang, B., Li, P., Cai, Q., Lin, W., and Liu, B., From Challenges To Opportunities: Towards Future Strategies And A Decision Support Framework For Oil Spill Preparedness And Response In Offshore Newfoundland And Labrador, Faculty Of Engineering and Applied Science, Memorial University The Harris Centre Applied Research Fund, Canada, 2011-2012

8. Preparing For Oil Spills: Contingency Planning, EPA Office of Emergency and Remedial Response, Understanding Oil Spills and Oil Spill Response

9. Aerial observation of marine oil spills, International Tanker Oil Pollution Prevention Federation ITOPF, 2011,United Kingdom

10. http://www.ccrs.nrcan.gc.ca/ccrs/eduref/tutorial/indexe.html> accessed at 14.01.2015.

11. Fundamentals of Remote Sensing, A Canada Centre for Remote Sensing Remote Sensing Tutorial

12. Skidmore, A., Environmental Modelling with GIS and Remote Sensing, ISBN 0-203-34631-9,Taylor and Francis, 2002, London

13. https://earth.esa.int/handbooks/asar/CNTR1-1-6.html accessed at, 07.12.2014.

14. G.Andreoli, B.Bulgarelli, B.Hosgood, D.Tarchi Hyperspectral Analysis of Oil and Oil-Impacted Soils for Remote Sensing Purposes, ISSN 1018-5593 ,EU Commission Directorate-General JRC Institute for the Protection and Security of the Citizen ,2007, Italy

15. Fingas, M., Brown, C, Review of oil spill remote sensing, Marine Pollution Bulletin, Volume 83, Issue 1, 15 June 2014, Pages 9-23, ISSN 0025-326X, http://dx.doi.org/10.1016/j.marpolbul.2014.03.059.

16. Camilla Brekke, Anne H.S. Solberg, Oil spill detection by satellite remote sensing, Remote Sensing of Environment, Volume 95, Issue 1, 15 March 2005, Pages 1-13, ISSN 0034-4257, http://dx.doi.org/10.1016/j.rse.2004.11.015.

17. Nand, J., Levy J., and Gao, Y., Advances in Remote Sensing for Oil Spill Disaster Management: State-of-the-Art Sensors Technology for Oil Spill Surveillance, Sensors 2008, 8, 236-255, ISSN 1424-8220,2008, USA

18. Palmer, D., Borstad, G.A. and Boxall, S.R. (1994). "Airborne Multi Spectral Remote Sensing of the January 1993 Shetlands Oil Spill", in Proceedings of the Second Thematic Conference on Remote Sensing for Marine and Coastal Environments: Needs, Solutions and Applications, ERIM Conferences, Ann Arbor, pp. II-546-558.

19. Pisano A., Development Of Oil Spill Detection Techniques For Satellite Optical Sensors And Their Application To Monitor Oil Spill Discharge In The Mediterranean Sea, PhD Thesis, Alma Mater Studiorum Università di Bologna, 2011, Italy

20. Carl E. Brown, Mervin F. Fingas, Review of the development of laser fluorosensors for oil spill application, Marine Pollution Bulletin, Volume 47, Issues 9–12, September–December 2003, Pages 477-484, ISSN 0025-326X, http://dx.doi.org/10.1016/S0025-326X(03)00213-3.

21. Nand, J.,Development of Laser Fluorosensor Data Processing System and GIS Tools for Oil Spill Response Department of Geomatics Engineering University of Calgary, September 2009

22. Fingas, M., and Brown, C., Oil Spill Remote Sensing: A Forensic Approach Emergencies Science and Technology Division, Environment Canada, Environmental Technology Centre, Ottawa, Ontario, Canada K1A 0H3

23. Akkartal, A., and Sunar, F., The Usage Of Radar Images In Oıl Spıll DETECTION A. F. Sunar The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. XXXVII. Part B8. Beijing 2008

24. Fingas M., Brown, C., Review of Oil Spill Remote Sensing, Presented at Spillcon 2000, Darwin, Australia, August 16, 2000.

25. Akar, S., Süzen M., and Kaymakci, N., Detection and object-based classification of offshore oil slicks using ENVISAT-ASAR images, Environ Monit Assess (2011) 183:409–423 DOI 10.1007/s10661-011-1929-6, 2011

26. Leifer,I., William J., Beatty,D., et al., State of the art satellite and airborne marine oil spill remote sensing: Application to the BP Deepwater Horizon oil spill, Remote Sensing of Environment, Volume 124, September 2012, Pages 185-209, ISSN 0034-4257, http://dx.doi.org/10.1016/j.rse.2012.03.024.

27. http://www.eia.gov/countries/regions-topics.cfm?fips=wotc&trk=p3,accesed at 05.02.2015

28. Ulusçu Ö., Özbaş, B., Altıok, T., Or, İ., Risk Analysis of Transit Vessel Traffic in The Strait of Istanbul, Journal of Risk Analysis Volume 29, Number 10, pp. 1454 - 1472 April 2008

29. https://www.kiyiemniyeti.gov.tr/Default.aspx?pid=23 accessed at 09.02.2015

30. Aerial Observation of Oil Pollution At Sea Operational Guide, CEDRE, 2006