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APPLICATION OF REMOTE SENSING TECHNOLOGIES ON INDUSTRIAL OUTFALLS

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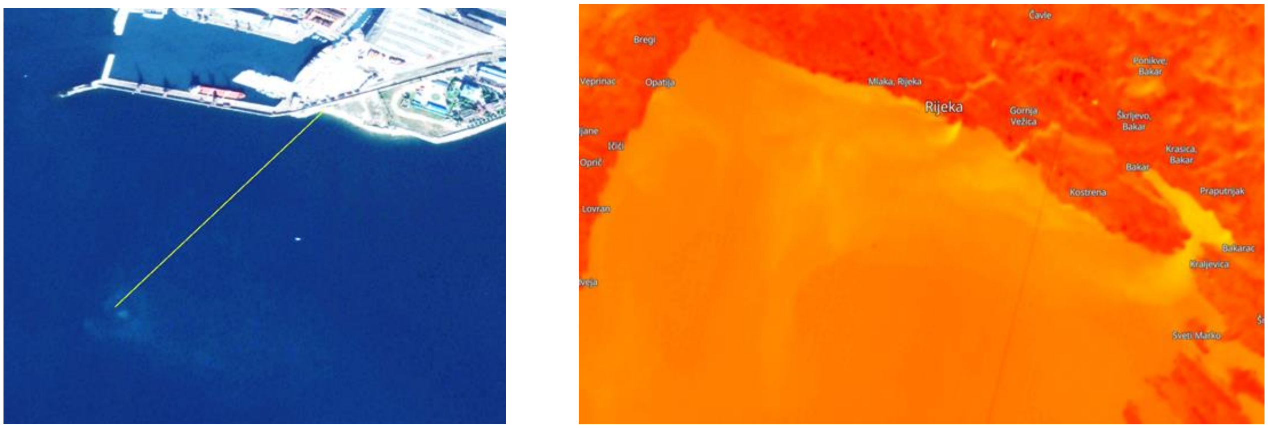
1 INTRODUCTION

Industrial effluents are a byproduct of various industries. They may contain harmful and toxic substances of organic or inorganic origin, such as pesticides, pharmaceuticals, hydrocarbons, detergents, and oils. In addition, industrial effluent can also come from thermal power plants in the coastal area, which use seawater for cooling, which they return to the environment after the process. Hence, the zone near the outlet has increased temperature, affecting the mortality and reduction of certain types of fish and algae, variations in the number of phytoplankton, and other ecological problems (Zhao *et al.*, 2015). Nowadays, an increasing amount of industrial wastewater from desalination processes is brine, which is considered a minor risk to public health but has a more significant impact on the environment (Lattemann and Amy, 2013). Due to the increase in population, the demand for drinking water has increased, especially on the islands and coastal areas. With the desalination process, drinking water is produced from sea or brackish water by removing suspended matter and dissolved minerals, mainly salt, and the effluent, i.e., brine, is discharged back into the coastal area. An increased amount of salt can potentially negatively affect the marine ecosystem, leading to the dehydration of cells and possible death of organisms (Missimer and Maliva, 2018). In addition, the brine may have a higher temperature than the environment and contain heavy metals and residues of hazardous chemicals applied in the process, such as anti-scale agents, flocculation agents, and coagulants (Panagopoulos and Haralambous, 2020.). The increasing hydrogen generation from renewable sources requires more freshwater. Consequently, a significant increase in this type of effluent is expected in the future.

Therefore, analysis and monitoring of the operation of industrial outfalls is essential to preserve the marine environment and public health. Previous research (Law and Tang 2016) proposes long-term monitoring after the outfall has been commissioned to study environmental effects. Historically, monitoring of wastewater outfalls was mainly obtained by in situ sampling methods to ensure water quality in coastal areas (Gierach *et al.*, 2017). Such practices have temporal and spatial limitations with high costs; hence, they are impractical for analyzing a larger coastal area. Therefore, in this research, we propose using remote sensing technologies for monitoring industrial outfalls.

2 REMOTE SENSING TECHNOLOGIES

Remote sensing includes various technologies such as unmanned aerial vehicle (UAV), helicopters, and satellites, which measure surface properties without direct contact so that they can have a wide range of temporal and spatial scales. Since remote sensing allows tracking changes in seawater properties over a long period, it is possible to compare properties before, during, and after the construction of marine outfalls (Amokranea *et al.,* 2021). Although satellite data is readily available and allows analysis of a large area, applications can be limited under cloudy weather and lower resolution compared to the other remote sensing technologies. UAVs and helicopters enable a high spatial and temporal resolution but have a much higher cost. Hence, balancing and choosing an adequate remote sensing method for outfall monitoring is essential. Optical remote sensors can measure water quality parameters, including chlorophyll, water temperature, turbidity, suspended inorganic material, colored dissolved organics, and colloidal matter (Shirke *et al.*, 2017). Measurements can be based on multispectral and hyperspectral sensors. Figure 1 represents examples of satellite image applications for marine monitoring. The left image shows visual changes in seawater color above the coastal outfall (represented by a yellow line in the city of Rijeka, Croatia) from a Google Earth Pro satellite image. The right image shows a thermal infrared sensor (TIRS) from Landsat 8 satellite above Rijeka Bay, Croatia. Several locations of water inflow with different temperatures can be observed along the coastline.



a) b)

Figure 1. Example of application of satellite data for marine monitoring using a) Google Earth Pro satellite image and b) Landsat 8 - Thermal Infrared Sensor (TIRS).

3 CONCLUSIONS

In this research, methods for remote sensing monitoring of industrial effluents are proposed. During outfall operations, it is necessary to ensure the quality of the coastal water meets legal regulations and preserves the marine environment. Instead of regular in situ sampling methods, the application of remote sensing methods is proposed. Strategies that can be used are listed and described to adequately choose the type of device, sensor, and type of image processing. Image analysis of remote sensing data is required to obtain useful information, including image collection, systematization, and postprocessing with machine learning algorithms. Due to the large number of possible remote sensing technologies, sensors, and analysis types, it is necessary to understand their application and limitations, advantages, and disadvantages to choose the type adequately. Depending on the location, type of effluent, and pollution from industrial outfalls, an adequate approach can be selected, which depends on the individual case.

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