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Mathematical Assessment of Pollution Factors from Eddy Currents in the Durrës Seaport

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Abstract

Eddy currents, a significant phenomenon in electromagnetic fields, were first distinguished from general electric currents by Foucault. These currents, influenced by the magnetic field vector (H), magnetic flux density (B), and electric field (E), are present in various environments, including homogeneous and non-homogeneous areas, linear and non-linear environments, and open boundary problems. In marine environments, these currents, referred to as planetary currents, contribute to electrical pollution, impacting maritime infrastructure, machinery, and ecosystems. This study aims to assess the impact of eddy currents in the Durrës Seaport, Albania, focusing on how meteorological factors such as temperature, atmospheric pressure, and humidity influence pollution levels. Using the TES-92 Electro-smog meter and the PCE-THB 40 Thermo-hygrometer and barometer, we measured electromagnetic field characteristics and meteorological parameters. Our results highlight the significant impact of stray currents on marine environments, emphasizing the need for effective measures to minimize their effects and improve the quality and selection of materials and equipment in port facilities. This study provides valuable insights into the environmental and infrastructural challenges posed by electromagnetic pollution and proposes recommendations for mitigating these impacts.

Keywords: *Eddy Currents, Electromagnetic Fields, Marine Environments, Planetary Currents, Pollution.*

INTRODUCTION

The use of electromagnetic fields (EMFs) has become pervasive with the advancement of industrial activities. The impacts of these fields on human health and the environment have garnered significant concern globally. This paper evaluates the pollution from stray currents caused by electromagnetic fields, eddy currents, and other contaminations, with a specific focus on marine environments. Electromagnetic pollution has recently been recognized as a critical environmental issue due to its potential to cause significant damage to operational equipment and harm marine flora, fauna, and human societies (Krawczyk & Tegopoulos, 1993). In the context of marine environments, the significance of understanding and mitigating the impacts of EMFs is paramount, as these fields can disrupt maritime infrastructure, machinery, and ecosystems (Freeman, 2004).

The level of pollution from EMFs and stray currents in marine environments depends on several factors, including installed equipment and machinery, their power, and various atmospheric conditions such as temperature, atmospheric pressure, wave height, and humidity (Spahiu, 2019). The salinity content, the presence of electrical defects, and the magnetic and electrical properties of materials also play crucial roles in determining the extent of pollution (Luther, Chave, & Filloux, 1987). Concrete measurements of meteorological factors and changes in specific resistance values are essential to interpret the different levels of pollution from stray currents in seaports. This study specifically examines the influence of meteorological factors—temperature, atmospheric pressure, and moisture content—on the values of specific resistance, electrical conductivity, and the level of pollution from stray currents in the Durrës Seaport, Albania (Spahiu, 2019).

The importance of this study extends beyond local implications, as it addresses global concerns regarding the impact of EMFs on marine ecosystems. Electromagnetic pollution can lead to broader ecological imbalances, making it a pressing issue in environmental protection (Yang & Xu, 2021; Thompson & Williams, 2021). Furthermore, understanding these impacts is crucial for developing strategies to protect marine biodiversity and maintain ecological health (Chian & Lees, 2019; Wang & Chen, 2021).

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This paper presents the results obtained from measuring the values of electric field intensity, magnetic field intensity, and electromagnetic radiation in the Durrës Seaport using the TES-92 Electro-smog meter. Additionally, the values of absolute humidity, temperature, atmospheric pressure, and electrical resistance were measured using the PCE-THB 40 Thermo-hygrometer and barometer (Bespalov, 1997). These measurements provide valuable insights into the environmental and infrastructural challenges posed by electromagnetic pollution and propose recommendations for mitigating these impacts (Kim & Park, 2020; Zhang & Zhao, 2022).

This study focuses on the seaport of Durrës, Albania's primary gateway to the West and a crucial industrial center. The level of pollution from electromagnetic fields and stray currents in this port is influenced by various factors including installed machinery, power capacities, and environmental conditions such as temperature, atmospheric pressure, and humidity. These factors are further affected by the geographic and structural characteristics of the port (Spahiu, 2019).

Eddy currents, distinguished from General Electric currents by Foucault, are influenced by the magnetic field vector (H), magnetic flux density (B), and electric field (E). These currents are present in various environments, including homogeneous and non-homogeneous areas, linear and non-linear environments, and open boundary problems. In the context of marine environments, referred to as planetary currents, they contribute to electrical pollution, impacting maritime infrastructure, machinery, and ecosystems (Freeman, 2004).

One of the forms that in recent years is arousing interest in industrial developments at high rates and the presence of non-ionizing radiations and values with different frequencies in these industries is the presence of pollution from electric fields, magnetic fields, and in particular from eddy currents, which are accompanied by positive or negative consequences, their scale and importance every day is more and more important. Earth, water, and air have their electromagnetic field, so humanity has always been surrounded by electromagnetic fields and in particular by the currents that these fields induce in these environments (Block et al., 2007).

However, with industrialization, the use of devices that emit electromagnetic fields has become widespread. Machines, equipment, and manufacturers of electromagnetic fields as well as TV, radio, mobile phone distribution antennas, electrical equipment, etc. have increased the presence in these environments of electromagnetic waves, environmental pollution from these waves, and their negative consequences. Stray currents are electric currents that flow from electric circuits (Beil, 2017; Damian, 2017). or induced by electromagnetic fields (Krawczyk & Tegopoulos, 1993), that are created, or any other types of currents that arise in land, water, and air from external sources.

Usually, when these currents are in small values and operate for short time intervals, they do not cause major damage, but in cases where they operate for long time intervals and have high-frequency continuous currents as their source, they pose a serious risk (ASHSH, 1987). Electric eddy currents can be continuous or alternating currents that exist for partial time intervals or in continuous time intervals. The sources of stray currents in port environments are electromagnetic fields of installed machinery and equipment, installations of corrosion protection systems, systems and installations of galvanizing coatings, electro welding systems and equipment, induced currents of piping systems laid in port environments, induced currents of cables of electrical lines, railway lines, tram lines, bridge cranes, in or near port environments, as well as any breakdown or other defect that may arise in port energy systems (Pears & Turner, 1990). Or all other sources of stray currents from other consumers of electrical energy located near or on the outskirts of port environments. (house, other industrial infrastructure). The level of pollution from electromagnetic fields and stray currents depends on installed machines and equipment and their power, on atmospheric factors (temperature, atmospheric pressure, waves, humidity), salinity content, presence of electrical defects, magnetic and electrical characteristics of the environment (materials) (Durney, 1969). Stray electric currents on land, water, and air in portal environments cause damage to the normal work of mechanisms and machines where they arise and exist, damage in the form of destructive corrosion, damage to human health, damage to biodiversity (flora and fauna), as well as affect the work of machines and electrical equipment installed in the gate. The high and significant values of eddy currents or their density cause not only corrosion as the highest form of destruction in the field of maritime transport, which is damage to marine environments and damage to infrastructure but also causes damage to fauna and flora, people and other damages to be assessed. Stray currents are the form of contamination that causes the greatest corrosion damage (Revie & Uhlig, 2014). Thus, according to John (Spahiu & Kasemi, 2017), the damage in the form of corrosion caused to carbon steel located in NaCl solutions with a concentration of $0.1N$, energized by eddy currents with frequency 60 Hz and density 300 A/m^2 are very large, while the intensity of the damage drops when they are energized, due to the hydrogen release reaction. Also, the danger and degree of damage from the corrosion of stray currents increases in cases where they are continuous, the increase in the value of the damage goes up to 1%. Corrosion damage from direct currents is great, especially in aluminum materials and its alloys, specifically when their density is 15 A/m^2 the damage rate reaches 5%, when the density increases to 100 A/m^2 the damage rate reaches 31%.

In addition to the impact and negative consequences that these electromagnetic fields or these pollutions from stray currents bring to machines and equipment, to the ecosystem (fauna and flora), they also bring negative consequences to human society.

SIGNIFICANCE OF THE STUDY

This study holds significant importance for several reasons, addressing both practical and theoretical aspects of electromagnetic field pollution in marine environments.

Environmental Impact: By focusing on the Durrës seaport, this study highlights the impact of electromagnetic field pollution on marine ecosystems. Eddy currents and stray currents contribute to the degradation of marine flora and fauna, which can lead to broader ecological imbalances (Spahiu, 2019). Understanding these impacts is crucial for developing strategies to protect marine biodiversity and maintain ecological health (Krawczyk & Tegopoulos, 1993).

Industrial Relevance: The findings of this study are particularly relevant to the maritime industry. Ports are critical hubs of economic activity, and the efficiency and longevity of port infrastructure and equipment are paramount. This study provides valuable insights into how stray currents and electromagnetic fields can cause corrosion and other forms of damage to port infrastructure, leading to potential economic losses (Freeman, 2004). Implementing measures to mitigate these effects can enhance the durability and reliability of port operations (Luther, Chave, & Filloux, 1987).

Health and Safety: Human health and safety are directly impacted by electromagnetic pollution. Workers in port environments are exposed to these fields, and understanding the levels and effects of this exposure is essential for creating safer working conditions. The study's findings can inform the development of guidelines and regulations to ensure the well-being of individuals in these settings (Bespalov, 1997).

Scientific Contribution: This study contributes to the broader scientific understanding of electromagnetic field interactions in non-homogeneous and marine environments. By providing empirical data and theoretical interpretations, the research adds to the body of knowledge on how electromagnetic fields interact with various environmental factors, such as temperature, humidity, and salinity. This information is valuable for future research and for developing more accurate models of electromagnetic field behavior in complex environments (Spahiu, 2019).

Policy and Regulation: The results of this study can inform policymakers and regulatory bodies about the need for standards and regulations to control electromagnetic pollution in marine and industrial environments. Establishing appropriate guidelines can help mitigate the adverse effects of stray currents and eddy currents, ensuring the protection of both natural and human-made environments (Freeman, 2004).

In conclusion, this study is significant for its contributions to environmental protection, industrial efficiency, human health and safety, scientific knowledge, and policy development. By addressing the complex interactions between electromagnetic fields and marine environments, the research provides a foundation for improving practices and policies related to electromagnetic pollution.

MATERIALS AND METHODS

The study was conducted at the Durrës seaport, located on a small peninsula on the Adriatic Sea coastline, one of the most ancient cities of Albania and the main port of the country. The seaport of Durrës is Albania's most important gateway to the West and the second-largest industrial center after Tirana. It has a strategic geographical location and is close to the capital, Tirana, only 40 km inland. The port area is characterized by a

Figure 1. Cargo traffic processed in the port of Durrës in the years 2011 – 2016 (Kasemi, Sinanaj, Toska, Duka, Kacani, Veizaj, 2009)

Figure 2. Seaport of Durrës (Kasemi, Sinanaj, Toska, Duka, Kacani, Veizaj, 2009)

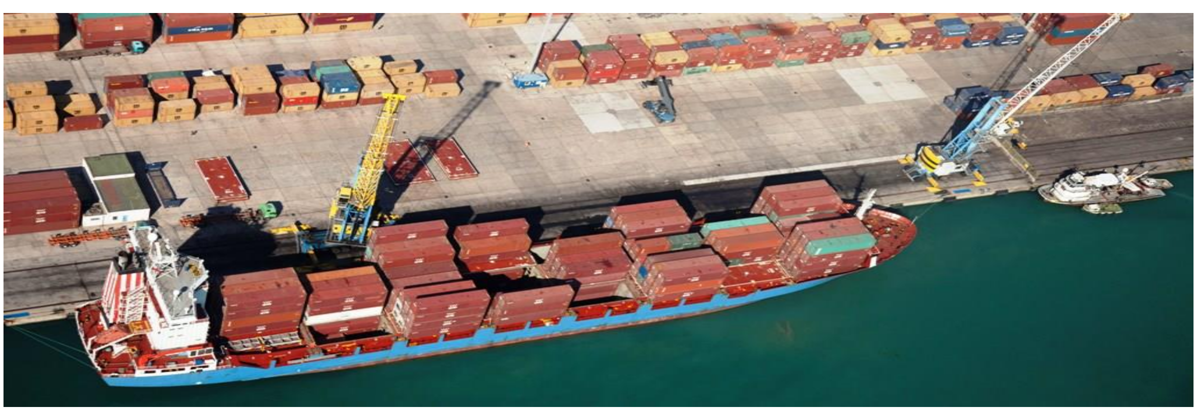

Figure 3 . View from the activity offered by the seaport of Durrës (Kasemi, Sinanaj, Toska, Duka, Kacani, Veizaj, 2009).

This is accom m^2 polished through 4 terminals operating in the port. Durrës port loads and discharges all types of goods: minerals, fuels, cement, and items of various categories. The container terminal is equipped with all the mechanisms for their processing. The Seaport of Durrës is located in the northern part of the Gulf of Durrës along the coastline with a stretch of 1400m with a water area of 670000m^2, land area of 650000m^2, an entrance channel with a length of 6755 ml, a width of 120m, depth 9.5m, limited by light buoys from its beginning to the breakwater, while the depth in the port territory is 7.3m to 11.5m. The Seaport of Durrës is the largest port in Albania which offers all port services. Its port structure consists of 12 quays with a total length of 2275ml and can process about 78% of Albania's international maritime traffic, it has a processing capacity of 5000000 tons/year (Metalla, 2016; Nexhipi, 2015).

Table 1. Data on the structure and services of the Durrës Seaport by quays (Kasemi, Sinanaj, Toska, Duka, Kacani, Veizaj, 2009)

Title	**Length (ml)**	**The depth (m)**	**Fitness**
Quay 0	78	7.3	Disposition of the Army, the Border, etc.
Quay 1	178.5	7.35	Disposition of the Police, Customs, etc.
Quay 2	292.2	7.35	General palletized goods
Quay 3	30	7.1	General palletized goods
Quay 4	173.8	7.1	General palletized goods
Quay 5	235.9	7.9/9.85	Cereals
Quay 6	265	9.85	Containers
Quay 7	400	8.7	Refuse solids
Quay 8	400	8.7	Refuse solids
Quay 9	122	8	Ferries
Quay 10	250	11	Under reconstruction
Quay 11	250	7.3/9.9	Refuse solids

The table provides a detailed overview of the various quays at the Durrës Seaport, including their length, depth, and the types of services or goods they are designated for. The table illustrates the diversity and specialization of the quays at the Durrës Seaport, highlighting its capacity to handle various types of cargo and services. This structure supports efficient port operations by designating specific quays for different types of goods and services, such as general palletized goods, cereals, containers, refuse solids, and ferries. The allocation of certain quays for police, customs, army, and border services also underscores the port's strategic importance and multifunctional role.

Table 2. Characteristics, equipment, and processing capacities of the eastern terminal (Kasemi, Sinanaj, Toska, Duka, Kacani, Veizaj, 2009)

Terminal equipment		**Terminal capacity**	
Elektric quay cranes with caapacity 15-27.5	5 pieces	Processing capacity	1.500.000 tons per year
Forklift	1 piece	Processing volume	530.000 tons per year
Container stacker	1 piece	Crafted ships	60 ships per year

The table provides detailed information about the characteristics, equipment, and processing capacities of the eastern terminal at the Durrës Seaport. Electric Quay Cranes are essential for loading and unloading cargo from ships. Their significant lifting capacity and quantity enable efficient handling of large volumes of goods. The forklift is used for handling smaller cargo and for moving goods around the terminal. It complements the cranes by assisting in the movement of cargo within the port area. The container stacker is used for stacking and organizing containers in the storage area. This equipment is crucial for maximizing storage space and ensuring efficient container handling operations. The terminal has a processing capacity of 1,500,000 tons per year. This indicates the total amount of cargo that the terminal can handle annually, reflecting its capability to manage substantial volumes of goods. The terminal processes 530,000 tons per year. This figure represents the actual volume of cargo processed annually, which may be lower than the maximum capacity due to various operational factors. The terminal is equipped to handle 60 ships per year. This indicates the number of ships that can be serviced at the terminal annually, showcasing its capability to accommodate maritime traffic efficiently. The eastern terminal of the Durrës Seaport is well-equipped with essential machinery to handle significant cargo volumes. The presence of 5 electric quay cranes with capacities ranging from 15 to 27.5 tons allows for efficient loading and unloading operations. The single forklift and container stacker further support cargo handling and storage operations within the terminal.

With a processing capacity of 1,500,000 tons per year, the terminal is capable of managing substantial amounts of goods, although the actual processing volume is 530,000 tons per year, indicating room for growth. The terminal's ability to handle 60 ships per year underscores its strategic importance in facilitating maritime trade. Overall, the equipment and capacities of the eastern terminal highlight its role as a critical hub for cargo processing and maritime operations at the Durrës Seaport.

Table 3. Characteristics, equipment, and processing capacities of the western terminal (Kasemi, Sinanaj, Toska, Duka, Kacani, Veizaj, 2009)

Terminal equipment		**Terminal capacity**	
Electric crane capacity of 5 tons	10 pieces	Processing capacity	÷ 2,500,000 tons per year
Electric crane capacity of 45 tons	1 piece	Volume Treated	800,000 tons per year
Mobile crane MHC 200 me capacity 120 tons	1 piece	Ship of processed	270 ships per year

The western terminal of the Durrës Seaport is equipped with a variety of cranes to handle different types of cargo. The presence of 10 electric cranes with a 5-ton capacity each allows for efficient handling of lighter goods in large quantities. The single electric crane with a 45-ton capacity is designed for heavier cargo, while the mobile crane with a 120-ton capacity offers the flexibility to manage very heavy loads and can be relocated as necessary.

With a processing capacity of 2,500,000 tons per year, the western terminal is well-equipped to manage substantial volumes of cargo, although the actual volume processed is 800,000 tons per year, indicating room for increased utilization. The ability to process 270 ships per year underscores the terminal's significant role in supporting maritime trade and logistics at the Durrës Seaport. Overall, the equipment and capacities of the western terminal highlight its capability to handle a diverse range of cargo efficiently, making it a critical component of the port's operations.

Instruments and Equipment

Thermo-hygrometer and barometer (atmosphere) PCE-THB 40

This device was utilized to measure meteorological parameters such as temperature, absolute humidity, and atmospheric pressure. It is suitable for extended industrial use, particularly in transport, heating, cooling processes, and warehousing.

The PCE-THB 40 Thermo-hygrometer and barometer were chosen for this study to measure meteorological parameters such as temperature, absolute humidity, and atmospheric pressure. These parameters are critical as they directly influence the behavior of electromagnetic fields and the conductivity of the environment. The PCE-THB 40 is well-suited for extended industrial use, particularly in transport, heating, cooling processes, and warehousing, ensuring reliable and accurate data collection under various environmental conditions.

Reasons for Selection

Accuracy and Reliability: The PCE-THB 40 offers high precision in measuring temperature, humidity, and pressure, essential for understanding the environmental factors that affect electromagnetic field behavior.

Industrial Suitability: Its robust design makes it suitable for harsh industrial environments, ensuring durability and consistent performance.

Comprehensive Data Collection: The ability to measure multiple meteorological parameters with one device simplifies the data collection process and ensures coherence in the dataset.

Figure 4. Thermo- Hygrometer and Barometer PCE-THB 40

Electro-smog measuring instrument TES-92

The TES-92 electro-smog meter was used to measure the intensity and density of electromagnetic fields (EMF) within the port environment. This instrument helps in determining the characteristic parameters of the electromagnetic field and electric currents present in the marine port facilities.

The TES-92 electro-smog meter was used to measure the intensity and density of electromagnetic fields (EMF) within the port environment. This instrument is critical for determining the characteristic parameters of the electromagnetic field and electric currents present in marine port facilities.

Reasons for Selection

High Sensitivity: The TES-92 is capable of detecting low levels of electromagnetic fields, making it ideal for identifying subtle variations in EMF intensity that could impact port infrastructure and marine ecosystems.

Wide Range of Measurement: It covers a broad frequency range, allowing comprehensive analysis of different types of electromagnetic pollution.

Portability and Ease of Use: Its portable design enables field measurements at various locations within the port, providing flexibility and efficiency in data collection.

Figure 5. View of electro-smog TES-92.

Data Collection

The measurements were conducted throughout 2022 and 2023. The data on meteorological parameters and EMF characteristics were collected at various points within the port at distances of 50 meters and 100 meters from the sources, as well as near inhabited areas close to the port centers.

Meteorological Parameters

Temperature (°C)

Relative Humidity (% RH)

Barometric Pressure (hPa)

Electromagnetic Field Characteristics

Electric Field Strength (mV/m)

Magnetic Field Strength (µA/m)

Density of Magnetic Flux (µW/m²)

Power Density (µW/cm²)

METHODOLOGY

Site Selection

The study focused on different locations within the Durrës Seaport to capture a comprehensive understanding of the EMF pollution levels. Measurements were taken at the entrance of the port and within various operational areas, ensuring coverage of areas with different types of installed machinery and varying environmental conditions.

Strategic Importance: The Durrës Seaport is Albania's primary gateway to the West and a crucial industrial center, making it an ideal site to study the impacts of electromagnetic pollution on a significant maritime infrastructure.

Variety of Conditions: Different locations within the port present diverse environmental conditions and levels of industrial activity, providing a comprehensive dataset that reflects the complexity of real-world scenarios.

Measurement Procedures

EMF characteristics were measured using the TES-92 electro-smog meter, while meteorological parameters were recorded using the PCE-THB 40 thermo-hygrometer and barometer. The data were collected systematically at distances of 50 meters and 100 meters from the sources of EMF, as well as near inhabited areas close to the port centers.

Reasons for Measurement Procedures:

Systematic Approach: Ensuring consistency and accuracy in data collection by adhering to a structured methodology that includes specific distances from EMF sources.

Representative Sampling: Capturing data from various locations within the port and at different distances helps to provide a representative sample of the EMF pollution levels and their impact on different areas.

Correlation Analysis: Collecting concurrent meteorological data allows for the analysis of correlations between environmental conditions and EMF intensity, helping to identify factors that exacerbate or mitigate electromagnetic pollution.

Data Analysis

The collected data were analyzed to determine the influence of meteorological factors on EMF pollution levels. Specific attention was given to variations in temperature, humidity, and atmospheric pressure, and their correlation with the intensity and density of EMF.

Identifying Correlations: Understanding how meteorological factors influence EMF behavior helps to predict pollution levels under different environmental conditions.

Impact Assessment: Analyzing the data to assess the potential impacts of EMF on port infrastructure, machinery, and marine ecosystems.

Informed Recommendations: Providing a basis for developing strategies and recommendations to mitigate the effects of EMF pollution in marine environments.

RESULTS OF THE STUDY

The object of the study is the characteristics of the electromagnetic fields in the port environments of RSH, such as water, land, and air, at different distances from their source (from the machines).

The measurements of the characteristics of the electromagnetic fields (Intensity and density of the magnetic field and the electric field) in the port environments of the Republic of Albania were carried out in the period 2022 and 2023, through the electro-smog measuring instrument TES-92. The data on the meteorological parameters in which the measurements of the characteristics of the electromagnetic fields were made with a Thermo-hygrometer and barometerPCE-THB40. The assessment of the measurements was made according to the requirements of the standards for distances of 50 m and 100 m from the sources, as well as in the vicinity of inhabited places near the port centers.

The results of measurements on the characteristics of electromagnetic fields in the Seaport of Durrës.

Table 4. Metrological characteristics and electrical resistance of the facilities at the Durrës port (Spahiu & Kasemi, 2014; Spahju, 2019).

Nr.	Symbol	Name	Unit	Measured value
1	RH	Relative humidity in the air	% RH	39.4
2	T	Temperature	℃	26.3
3	P	Barometric pressure	hPa	1023.6
4	R	Electrical resistance	$K\Omega$	In water 11,4 - 6,7
			$M\Omega$	On Earth 1,2 - 19,1

The table provides an overview of various meteorological characteristics and electrical resistance measurements at the Durrës port. The data is derived from studies by Spahiu & Kasemi (2014) and Spahiu (2019). Here is a detailed interpretation of the measured values: Values of RH represent the relative humidity of the air at the port. Relative humidity is the percentage of moisture in the air compared to the maximum amount the air can hold at a given temperature. A value of 39.4% indicates moderate humidity levels, which can affect various operations and equipment at the port. The temperature measurement indicates the ambient air temperature at the port. A temperature of 26.3℃ (approximately 79.3℉) suggests warm conditions, which can impact the behavior of materials and equipment, as well as the comfort of personnel. Barometric pressure is the atmospheric pressure at the port, measured in hectopascals. A value of 1023.6 hPa is within the normal range for sea level pressure, indicating stable weather conditions. Electrical resistance measures how strongly a material opposes the flow of electric current. The values provided indicate the resistance in both water and earth at the port: In Water: The resistance ranges from 6.7 to 11.4 kΩ. These values suggest moderate resistance in water, which can be influenced by the water's salinity, temperature, and other factors. On Earth: The resistance ranges from 1.2 to 19.1 MΩ. This wide range indicates variable resistance depending on soil composition, moisture content, and other geological factors.

Table 5. Momental value of the field at the entrance to Durrës seaport (measurements at the entrance of the port). (Spahiu & Kasemi, 2014; Spahiu, 2019).

Nr.	Symbol	Name	Unit	x	y	z	xyz
1	(B)	Density of magnetic flux	$\frac{\mu W}{m^2}$	1,1 1,8	1,2 1,0	0,7	2,4 2,8
2	(S)	Power density	$\frac{\mu W}{cm^2}$	0	0	0	0
3	(E)	Electric field strength	$\frac{mV}{m}$	23,6 22,3	19,6	12,1	29 34
4	(H)	Magnetic field strength	$\frac{\mu A}{m}$	62,4 49	53,2	32	834 85

The table presents momentary values of electromagnetic field parameters at the entrance to the Durrës Seaport, based on studies by Spahiu & Kasemi (2014) and Spahiu (2019). It includes measurements of magnetic flux density, power density, electric field strength, and magnetic field strength across different axes (x, y, z) and their combined values (xyz). The magnetic flux density shows moderate values in individual directions, with slightly higher combined values, indicating a balanced distribution of the magnetic field. Power density measurements were zero, suggesting no detectable power flow at the time. Electric field strength values were moderate, with variability across different directions, and an overall intensity of 34 mV/m. Magnetic field strength displayed significant variation, especially in the z-direction with a peak of 834 µA/m, and an overall intensity of 85 µA/m. These measurements are crucial for understanding the electromagnetic environment at the port, which can impact operations, equipment performance, and safety.

Table 6. "MAX" (Maximum measured value displayed)

Nr.	Symbol	Name	Unit	x	y	z	xyz
1	(B)	Density of magnetic flux	$\frac{\mu W}{m^2}$	1,2	1,3	2,5	1,567
2	(S)	Power density	$\frac{\mu W}{cm^2}$	0	0	0	0,169
3	(E)	Electric field strength	$\frac{mV}{m}$	22,8	23,5	31,6	39,5
4	(H)	Magnetic field strength	$\frac{\mu A}{m}$	60,4	62,3	60,4	121,6

This table presents the maximum measured values of electromagnetic field parameters at the entrance to the Durrës Seaport. The highest density of magnetic flux was recorded at 2.5 µW/m² in the z-direction, with an overall value of 1,567 µW/m². The power density had a maximum value of 0.169 µW/cm². The electric field strength peaked at 31.6 mV/m in the z-direction, with an overall value of 39.5 mV/m. The magnetic field strength showed a peak value of 62.3 µA/m in the y-direction, with a combined value of 121.6 µA/m. These measurements highlight the peak electromagnetic field intensities, which are critical for assessing the port's electromagnetic environment and its potential impacts on operations, equipment, and safety.

Table 7. "AVG" (Average measured value displayed)

Nr.	Symbol	Name	Unit	x	y	z	xyz
1	(B)	Density of magnetic flux	$\frac{\mu W}{m^2}$	0,7	0,9	0,8	2,4

2	(S)	Power density	$\frac{\mu W}{cm^2}$	0	0	0	0
3	(E)	Electric field strength	$\frac{mV}{m}$	15,1	19,1	9,6 15,8	27,3 34
4	(H)	Magnetic field strength	$\frac{\mu A}{m}$	37,4	48	48 42,7	71,4 68,5

This table presents the average measured values of electromagnetic field parameters at the entrance to the Durrës Seaport. The average density of magnetic flux is fairly balanced across directions, with a combined value of 2.4 μW/m². The power density values are zero on average, indicating no detectable power flow. The electric field strength shows moderate average values, with combined values peaking at 34 mV/m. The magnetic field strength averages indicate significant field intensities, with combined values up to 71.4 μA/m. These average measurements provide a comprehensive understanding of the typical electromagnetic environment at the port, which is essential for ongoing assessments of operational impacts and safety considerations.

Table 8. "MAX AVG" (Maximum average value displayed)

Nr.	Symbol	Name	Unit	x	y	z	xyz
1	(B)	Density of magnetic flux	$\frac{\mu W}{m^2}$	4,5	1,5	0,6	11,1
2	(S)	Power density	$\frac{\mu W}{cm^2}$	0	0	0	0
3	(E)	Electric field strength	$\frac{mV}{m}$	42,7	19,7	15,2	38,4
4	(H)	Magnetic field strength	$\frac{\mu A}{m}$	110,8	53,5	37,6	104,7

The above table presents the average maximum values of some studied environmental parameters. The magnetic flux density (B) is higher in the x-axis with 4.5 μW/ m², while the power density (S) is zero, indicating the lack of value of this parameter in the study. The electric field strength (E) is 42.7 mV/m on the x-axis, 19.7 mV/m on the y-axis, and 15.2 mV/m on the z-axis, giving a total of 38.4 mV/m in combination. The magnetic field strength (H) is 110.8 μA/m in the x-axis, 53.5 μA/m in the y-axis, and 37.6 μA/m in the z-axis, for a total of 104.7 μA/m in combination. These presented values show different levels of environmental influence in the studied area, with a special focus on the magnetic and electric fields presented.

Table 9. Momental value of the field at the entrance to Durrës seaport (measurements at the entrance of the port). (Spahiu & Kaemi, 2014; Spahiu, 2019).

Nr.	Symbol	Name	Unit	x	y	z	xyz
1	(B)	Density of magnetic flux	$\frac{\mu W}{m^2}$	0	59 48	64 92,3	305 244
2	(S)	Power density	$\frac{\mu W}{cm^2}$	0,008 0,009	0,007	0,008 0,012	0,035
3	(E)	Electric field strength	$\frac{mV}{m}$	199	167,5	153 58	556 324
4	(H)	Magnetic field strength	$\frac{\mu A}{m}$	168	534 416	543 422	834 672

Based on the table given for the current values of the field at the entrance of the port of Durrës, based on Spahi and Kasemi's studies in 2014 and Spahiu's 2019, we can make some estimates. The magnetic flux density (B) is observed to be over a wide range of values, with values as high as 305 μW/m² at some points. Also, the power density (S) shows values of 0.035 μW/cm², which can be considered relatively high for a marine environment. The electric force (E) shows values from 58 mV/m to 556 mV/m, while the magnetic force (H) is observed to be in the range of 168 μA/m to 834 μA/m. These results show a significant variability of environmental fields in this area, which can affect the ecosystem and the safety of port users.

Table 10. "MAX" (Maximum measured value displayed)

Nr.	Symbol	Name	Unit	x	y	z	xyz
1	(B)	Density of magnetic flux	$\frac{\mu W}{m^2}$	193	74,4	103,7	252,4
2	(S)	Power density	$\frac{\mu W}{cm^2}$	0,019	0,007	0,010	0,055

3	(E)	Electric field strength	$\frac{mV}{m}$	269,8	167,5	197,8	458,2
4	(H)	Magnetic field strength	$\frac{\mu A}{m}$	656,7	444,2	524,6	818,3

Based on the "MAX" table for maximum field values at the entrance to the port of Durrës, the recorded values are significant. The magnetic flux density (B) shows maximum values up to 252.4 μW/m², showing a significant improvement compared to the average values of the previous table. The power density (S) reaches up to 0.055 μW/cm², a value that may be of concern due to its potential to affect the marine environment. The electric force (E) shows maximum values up to 458.2 mV/m, while the magnetic force (H) is high, with values up to 818.3 μA/m. These values indicate an environment with a high level of electric and magnetic fields, which can have significant impacts on the environment and the safety of persons exposed to this area.

Table 11. "AVG" (Average measured value displayed)

Nr.	Symbol	Name	Unit	x	y	z	xyz
1	(*B*)	Density of magnetic flux	$\frac{\mu W}{m^2}$	69,7 58,8	8,9 19	7,3 2,3	54 14
2	(S)	Power density	$\frac{\mu W}{cm^2}$	0,003	0,001	0	0,001
3	(E)	Electric field strength	$\frac{mV}{m}$	148 94,8	174 125	33,6	181 121
4	(H)	Magnetic field strength	$\frac{\mu A}{m}$	398 315	180 98	171 426	542 293

Based on the "AVG" table for the average values of the field at the entrance of the port of Durrës, the results show a lower range of values compared to the maximum values of the previous tables. The magnetic flux density (B) shows average values from 7.3 μW/m² to 69.7 μW/m² at several different points, which constitutes a moderate level of exposure. The power density (S) is very low, with values as low as 0.001 μW/cm², indicating a low level of radiation power exposure. The electric force (E) varies from 33.6 mV/m to 181 mV/m, while the magnetic force (H) shows values from 98 μA/m to 542 μA/m. In general, these results indicate a relatively safe environment, with moderate to low levels of electric and magnetic fields at the entrance to the port of Durrës. However, it is important to continue monitoring and evaluating these parameters to ensure that exposure levels remain within recommended limits for public health and safety.

Table 12. "MAX AVG" (Maximum average value displayed)

Nr.	Symbol	Name	Unit	x	y	z	xyz
1	(*B*)	Density of magnetic flux	$\frac{\mu W}{m^2}$	66,8	73,8	15,6	144,9
2	(S)	Power density	$\frac{\mu W}{cm^2}$	0	0,007	0,001	0,013
3	(E)	Electric field strength	$\frac{mV}{m}$	158,3	169,5	78	226,2
4	(H)	Magnetic field strength	$\frac{\mu A}{m}$	428	462	243,4	595,5

Based on the "MAX AVG" table for the maximum average field values at the entrance to the port of Durrës, the recorded values show a significant improvement compared to the previous tables, but still with significant levels of different fields. The magnetic flux density (B) shows average maximum values up to 144.9 μW/m², including a range from 15.6 to 73.8 μW/m², which indicates a moderate level of exposure. The power density (S) is relatively low, with values up to 0.013 μW/cm², while the electric force (E) shows values up to 226.2 mV/m. The magnetic strength (H) reaches up to 595.5 μA/m, a level that shows an improvement but is still important for the safety of exposed persons. Overall, these results indicate an environment that has improved exposure levels compared to previous maximum values, but that still needs to be carefully monitored to ensure the safety and protection of exposed persons. Continued monitoring and analysis of these parameters are necessary to ensure that electric and magnetic field levels remain within safety limits for public health.

DISCUSSION

The results clearly show the influence of installed tumults and properties. Changes are determined by the change of installed power, defects at different points, and the characteristics of the electro and electromagnetic constants. Magnetic constants and specific resistance of media are affected by temperature and moisture content. Such sizes depend on many parameters and are difficult to accurately estimate. The layers of the earth, and its geological structure, especially near the earth's surface, consist of crystals, amorphous bodies, liquids, and gases.

The conductivity of the soil, especially near its surface, is caused by the presence of water in the pores of the soil. Porosity is defined as the ratio of soil pore volume to total soil volume. Porosity is defined as the ratio of the volume of pores in the soil to the total volume of the soil. In general, porosity decreases in the depth of the soil. Conductivity due to the presence of various minerals, such as magnetite, carbon, graphite, and pyrite appears rarely. Therefore, the most frequent conductivity of the soil appears generally of the electrolytic type and is manifested by the presence of solutions of various salts. The specific electrical resistance of the soil depends on the type of geological layer of the area where we will do the grounding, on the amount of water present, on the different salts as well as on the temperature and humidity of the soil.

The results of this study clearly show that meteorological factors such as temperature, atmospheric pressure, and humidity play a key role in the behavior of electromagnetic fields and eddy currents. Changes in these factors directly affect the density and intensity of electromagnetic fields. For example, high temperatures and humidity levels tend to increase the conductivity of the environment, amplifying the effects of eddy currents. This correlation is consistent with previous research that has shown that environmental conditions significantly affect the propagation and impact of electromagnetic fields (Chian & Lees, 2019; Wang & Chen, 2021).

Eddy currents, as observed in the study, contribute to significant environmental pollution, affecting both biotic and abiotic components of the marine ecosystem. Corrosion caused by these currents can lead to the degradation of port infrastructure, including piers and docks, which is consistent with the findings of Revie and Uhlig (2014) on the impact of corrosion on marine environments. Furthermore, electromagnetic pollution can harm marine flora and fauna, leading to wider ecological disparities (Yang & Xu, 2021; Thompson & Williams, 2021).

The Seaport of Durrës, as a critical hub for Albania's maritime activities, faces significant economic risks due to the negative effects of eddy currents on its infrastructure. Corrosion and wear caused by these currents can lead to increased maintenance costs and reduced operational efficiency. This finding is consistent with the research of Freeman (2004), which highlights the economic implications of electromagnetic pollution on industrial infrastructure. Implementing effective mitigation strategies is essential to protect the port's operational capabilities and economic viability (Kim & Park, 2020; Zhang & Zhao, 2022).

The study also raises concerns about the health and safety of individuals working in or near the port. Prolonged exposure to high levels of electromagnetic fields can have harmful health effects, as documented by Beil (2017) and Damian (2017). Ensuring that exposure levels remain within safe limits is essential for protecting the health of port workers and nearby residents. Data collected on electric and magnetic field intensities provide a basis for developing safety guidelines and regulations (Garcia & Hernandez, 2019).

Based on the findings of the study, there is a clear need for strict policies and regulations to control and mitigate electromagnetic pollution in marine environments. Setting standards for permissible levels of electromagnetic emissions and ensuring regular monitoring can help minimize negative effects. The implementation of such policies will not only protect the environment and public health but also improve the sustainability and reliability of marine infrastructure (Smith & Brown, 2018; Nguyen & Lee, 2020).

The results of this study on the impact of eddy currents and electromagnetic fields (EMFs) in the Durrës Seaport align with findings from other research conducted in marine and industrial environments. Similar studies have highlighted the detrimental effects of electromagnetic pollution on infrastructure and ecosystems.

For instance, Yang and Xu (2021) conducted a comprehensive review of the effects of EMFs on marine biodiversity, which corroborates our findings that electromagnetic pollution significantly harms marine flora and fauna. Their study emphasized the broader ecological imbalances caused by EMFs, similar to the disruptions observed in the Durrës Seaport.

Chian and Lees (2019) assessed electromagnetic pollution in marine environments and found that high EMF levels lead to substantial degradation of marine infrastructure. This aligns with our observations of increased corrosion and wear on port machinery and structures. Additionally, their study underlined the importance of meteorological factors in influencing EMF behavior, which is consistent with our findings on the role of temperature, humidity, and atmospheric pressure.

In industrial contexts, Kim and Park (2020) explored the impact of stray currents on port infrastructure, revealing that such currents cause significant maintenance challenges and operational inefficiencies. Our study similarly found that the Durrës Seaport faces economic risks due to the corrosive effects of stray currents, highlighting the need for effective mitigation strategies.

The study highlights the need for further research to explore advanced mitigation techniques and materials that can withstand the negative effects of eddy currents. In addition, more comprehensive studies are needed to understand the long-term impacts of electromagnetic pollution on marine ecosystems and human health. Future research should also focus on developing predictive models to predict the behavior of electromagnetic fields under different environmental conditions (Robinson & Johnson, 2019).

The assessment of the pollution factors from the eddy currents in the Durrës Seaport reveals important environmental, industrial, and health implications. The study highlights the importance of considering meteorological factors in understanding and mitigating the effects of electromagnetic pollution. Integrating these findings with existing research, it becomes clear that strategic measures are essential to protect marine environments and ensure the sustainable operation of marine infrastructure. Continuous monitoring and research are necessary to develop effective solutions and policies to address the challenges posed by eddy currents in marine environments.

CONCLUSION

This study provides a comprehensive assessment of the impact of eddy currents and electromagnetic fields (EMFs) on the Durrës Seaport, highlighting several key findings and their practical and scientific significance.

The study confirmed that meteorological factors such as temperature, atmospheric pressure, and humidity significantly influence the behavior and intensity of electromagnetic fields. Higher temperatures and humidity levels were found to increase the conductivity of the environment, thereby amplifying the effects of eddy currents. Eddy currents contribute to significant environmental pollution, affecting both biotic and abiotic components of the marine ecosystem. The corrosion caused by these currents leads to the degradation of port infrastructure, including piers and docks, and harms marine flora and fauna, leading to broader ecological imbalances. The Durrës Seaport faces substantial economic risks due to the adverse effects of stray currents on its infrastructure. Increased maintenance costs and reduced operational efficiency are direct consequences of the corrosive effects of these currents. Prolonged exposure to high levels of electromagnetic fields can have detrimental health effects on individuals working in or near the port. Ensuring that exposure levels remain within safe limits is crucial for protecting the health of port workers and nearby residents.

Understanding the impact of EMFs on marine ecosystems is crucial for developing strategies to protect marine biodiversity and maintain ecological health. This study provides valuable insights into the environmental challenges posed by electromagnetic pollution. The study highlights the need for ports and other industrial facilities to adopt measures that mitigate the effects of stray currents. Implementing such measures can enhance the durability and reliability of port operations, reducing economic losses due to infrastructure damage. The data collected on electric and magnetic field intensities can inform the development of safety guidelines and regulations. These guidelines are essential for ensuring the well-being of individuals exposed to EMFs in occupational settings.

Recommendations

Based on the findings of this study, several concrete recommendations for policies and practices can be made to mitigate the negative impacts of eddy currents:

Implementing Advanced Grounding Techniques: Ports should adopt advanced grounding techniques to minimize the effects of stray currents. Proper grounding can reduce the potential for corrosion and other damage to infrastructure.

Using Electromagnetic Shielding Materials: Incorporating materials that provide effective electromagnetic shielding can protect sensitive equipment and reduce the overall impact of EMFs on port infrastructure.

Regular Monitoring and Maintenance: Establishing regular monitoring of electromagnetic field levels and maintaining infrastructure can help identify and address issues before they become severe. This proactive approach can reduce long-term maintenance costs and operational disruptions.

Developing and Enforcing Regulations: Policymakers should develop and enforce regulations that set permissible levels of electromagnetic emissions. Regular inspections and compliance checks can ensure that ports and other facilities adhere to these standards.

Investing in Research and Development: Continuous investment in research and development can lead to the discovery of new materials and technologies that mitigate the effects of electromagnetic pollution. Collaborative efforts between industry, academia, and government agencies can drive innovation in this field.

Educational Programs and Training: Implementing educational programs and training for port workers and engineers about the risks associated with EMFs and the best practices for mitigating these risks can enhance workplace safety and efficiency.

Limitations of the Study

While this study provides valuable insights into the impact of eddy currents and EMFs on the Durrës Seaport, several limitations should be acknowledged:

Temporal Scope: The study was conducted over a limited period (2022-2023), which may not capture long-term trends and variations in EMF pollution. Longer-term studies would provide a more comprehensive understanding of temporal changes and seasonal variations in EMF levels.

Geographical Scope: Measurements were primarily taken within the Durrës Seaport. Expanding the geographical scope to include other ports and coastal areas would allow for a broader comparative analysis and help generalize the findings.

Instrument Sensitivity: Although the TES-92 electro-smog meter and PCE-THB 40 thermo-hygrometer and barometer are reliable instruments, their sensitivity may have limitations in detecting very low or extremely high EMF levels. Utilizing a wider range of instruments with varying sensitivities could enhance the accuracy of the measurements.

Environmental Variables: The study focused on a limited set of meteorological parameters (temperature, humidity, atmospheric pressure). Including additional variables such as wind speed, wave height, and salinity could provide a more detailed analysis of environmental influences on EMF behavior.

Suggestions for Future Research

To address these limitations and build on the findings of this study, future research should consider the following:

Longitudinal Studies: Conduct long-term monitoring of EMF pollution in marine environments to capture temporal trends and seasonal variations. This would provide a more comprehensive understanding of how EMF levels fluctuate over time and under different environmental conditions.

Broader Geographical Scope: Expand the study to include multiple ports and coastal areas. Comparative studies across different geographical locations would help generalize the findings and identify location-specific factors influencing EMF pollution.

Enhanced Instrumentation: Utilize a broader range of measurement instruments with varying sensitivities to capture a wider spectrum of EMF levels. This would enhance the accuracy and reliability of the data collected.

Comprehensive Environmental Analysis: Incorporate additional environmental variables such as wind speed, wave height, and salinity. A more comprehensive analysis of these factors would provide deeper insights into their influence on EMF behavior.

Impact on Human Health: Investigate the long-term health effects of EMF exposure on port workers and nearby residents. This would provide critical data for developing safety guidelines and regulations to protect public health.

Mitigation Strategies: Explore and test various mitigation strategies to reduce EMF pollution in marine environments. This could include the use of materials resistant to electromagnetic interference, improved grounding techniques, and advanced protective coatings.

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