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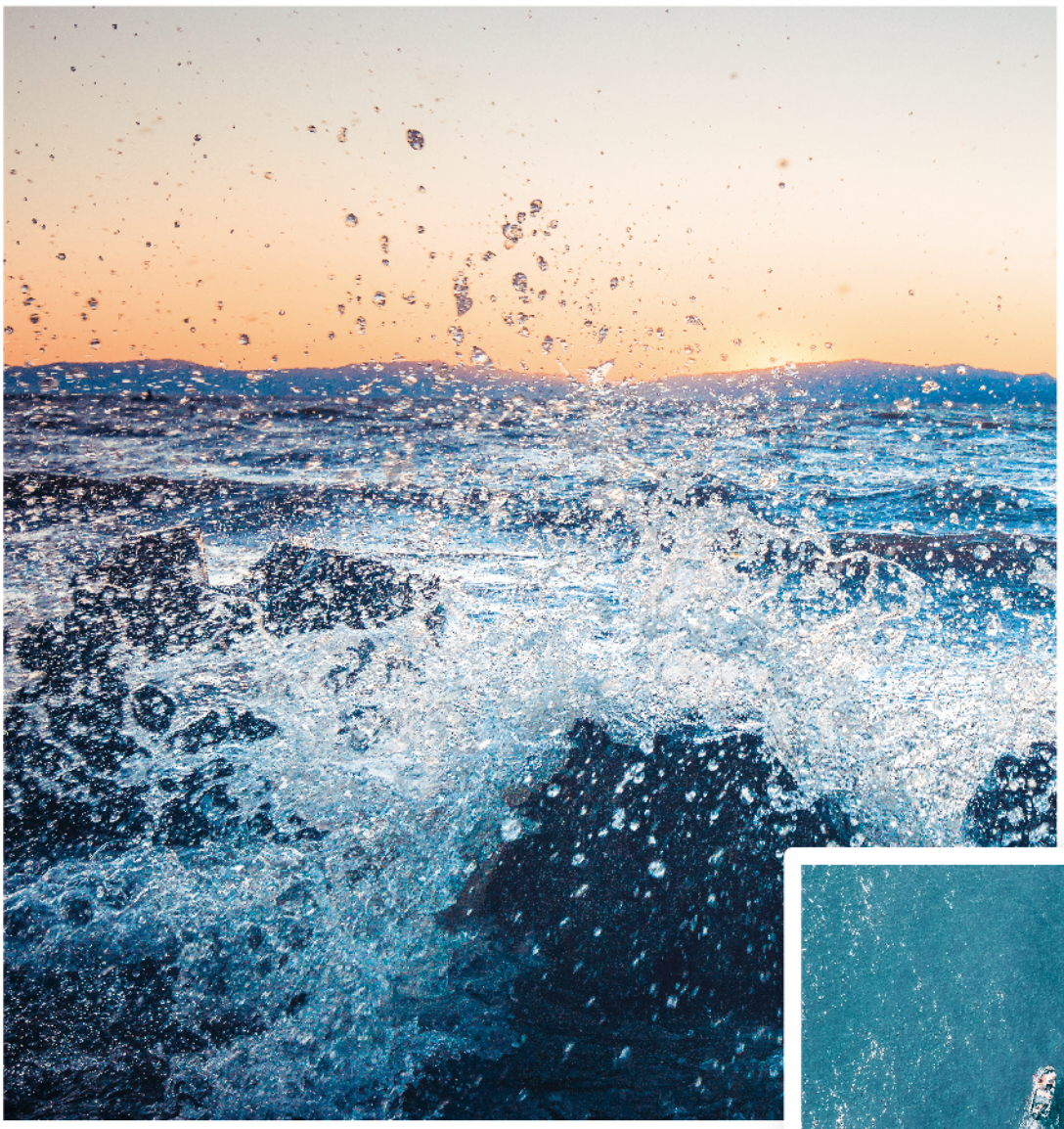

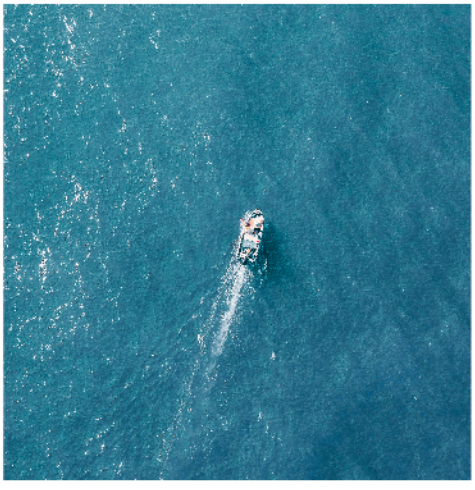

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Volume 2 | Issue 2 | July 2020 | Page 1-38

Journal of Geriatric Medicine

Contents

Article

Sustainable Marine Structures
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ARTICLE

Study the Role of Maritime Energy Management in Achieving the United Nations Sustainable Development Goals (UN SDGs), in particular, Goal 7, in Oman Maritime Community

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ABSTRACT

Sustainability is a concept for achieving integration and balance in development to preserve and use resources properly by providing new solutions to overcome structural, social and economic misconceptions to prevent further degradation and waste of natural resources and create a better future for human societies. Sustainable development can be defined as a strategy for the correct use of resources, by modifying and redefining consumption patterns and avoiding one-sided development approaches. Therefore, sustainable development is defined as a long-term and unlimited solution for aligning different concepts (social, economic, and environmental), seemingly independent but related and influencing each other. This paper examines the challenges and capacities of the Oman Maritime Community and Maritime Energy Management's role in terms of sustainable development. To analyze this issue, the role of key players in Oman's maritime industry, such as the Oman Fisheries Company and the Oman Shipping Company, has been studied with the five main indicators of sustainable development goals, including people, the planet, peace, welfare, and partnership.

1. Introduction

In 2015, the UN General Assembly issued a strategic document called the Sustainable Development Goals-Agenda 2030, and the member states committed to doing it. This document contains 17 essential goals for sustainable development in different fields with the same approach and the goal [31].

These 17 goals, along with 169 related targets, encompass three key areas, including environmental, economic, and social, that significantly impact the planet and humanity as vital issues [31]. According to the agenda 2030, all countries are determined and undertake to provide and design a roadmap and plan of action on ending poverty and hunger of the people, protect the planet, prosperity for humanity, peace and mobilize resources for the implementation of the objectives of the Global Partnership on What is stated in the Sustainable Development Goals.

The most important factor for achieving these goals is the determination and responsibility of all people and all stakeholders and industries to achieve them. The maritime industry is one of the main players in achieving these goals. The responsibility of all people, stakeholders, and

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industries to achieve these goals. The maritime industry is one of the main players in achieving these goals.

Therefore, as the industry's principal source, the International Maritime Organization (IMO) has issued and clarified the necessary roadmaps and guidelines in all areas relevant to these goals for sustainable development[8]. Among these areas is the topic of energy and its management, as identified in goal number seven and has been addressed.

Therefore, the International Maritime Organization, in the field of energy and its management, focuses on facilitating international cooperation and global partnerships for the deployment and access to modern, sustainable, and affordable energy in the maritime industry, which is mentioned as the Global Maritime Energy Efficiency Partnerships Project (GloMEEP) and being implemented in partnership with the United Nations Development Programme (UNDP), Global Environment Facility (GEF) and IMO [8].

The project aims to provide a platform and a framework to build the capacity needed to increase energy efficiency and enhance marine energy management by increasing participation at national, regional, and global levels, focusing on developing countries [8].

Another important project, which IMO is currently undertaking is the Global Maritime Technology Cooperation Center (MTCC) Network (GMN) that focuses on mitigating the impact of the maritime industry on climate change and providing technical solutions to developing and less developed countries [4].

The Maersk shipping company has defined the company's position and responsibility for each of the sustainable development goals and the type of impact those goals have, on the company's goals and vision [12].

In 2019, for example, five Pacific states entered into a treaty that would emit greenhouse gas emissions from the ship's fuel consumption. In the first phase, and by 2030, it has reduced by 40 percent, and by 2050, it will reach zero [32]. Another example is The Blue Generation Project, which is currently underway in the European economic area and aims to create sustainable employment for young people without a job [1].

This paper examines Oman's maritime industry and its maritime energy management role in achieving sustainable development goals, with a particular view to goal seven on energy and energy management.

2. Literature Review- Maritime Industries and SDGs

In a study on the maritime industry's role in achieving the goals of sustainable development, five areas have been mentioned as opportunities. All sustainable development goals are within the scope of these opportunities and include the Paris Agreement, sustainable infrastructure, ocean life protection, sustainable ocean economies in the future, and accountability for practical action in this area[3].

In energy, which is defined under goal 7, the development and implementation of methods to reduce greenhouse gas emissions on ships and other marine industries are emphasized through supportive strategies, development of standards, and financial incentives. Also, the extraction of energy from oceanic resources or available in the oceans with the aim of sustainability in the ocean economics is one of the opportunities expressed in this study [3].

A research on the shipping industry's effectiveness shows that in viewpoint of the type and intensity of the effect, very directly and with high impact, shipping can affect goals 7 and 13 related to clean energy and climate action, respectively. The effects of shipping on other targets are moderately direct or indirect, with moderate to low intensity. On this basis, shipping can help renewable energy by creating the necessary platform and providing support and technical services, for the extraction, harvesting and distribution of this type of energy [3].

Moving to alternative fuels with zero emissions, using renewable energy, or improving energy efficiency, and providing a platform for developing innovative methods in all ship operations, are other things that can be considered in terms of achieving sustainable Shipping and fulfillment of agenda 2030. Looking at the global shipping fleet in regard of number, the effectiveness of implementing strategies related to renewable energy can be very high in achieving the targets set in Goal 7 [3].

Maritime industry can play a key role in this by synergizing partnerships with the public, private sectors, other industries and its powerful IMO (International Maritime Organization) platform. Besides, the maritime industry can take effective steps towards achieving Goal 17 by exchanging experiences and technical knowledge in various fields and participating in developing strategies and roadmaps for sustainable development [3].

Another study points out the limitations that researchers face in examining the maritime industry's current position concerning the current situation and the vision of sustainable development goals. Lack of access to information from many private shipping companies, providing various interpretations and interpretations of Goal 10 as reducing inequality, are among these limitations. As this study emphasizes the fundamental role of the shipping and maritime industry in reducing inequality by increas-

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ing and expanding access to logistics resources, it points to further research on the role of shipping and logistics in Goal 10 [33].

According to this study, most of the information used in the analysis of the current situation and the maritime industry's interaction with the agenda 2030 has been done generally and mainly based on the data of container companies or liner lines. Accordingly, although container companies account for a large volume of global Shipping, they may not fully reflect other actors' conditions in the field of maritime transport [33].

By defining the concept of sustainable Shipping, the International Maritime Organization has identified areas in which the maritime industry can assist and support the implementation and achievement of each of the sustainable development goals and, ultimately, the achievement of a sustainable planet. IMO plays an irreplaceable role in facilitating global trade by providing a suitable platform for cooperation and participation of all countries in maritime transport, as the least expensive transportation method with the most efficient energy consumption. According to this approach, sustainable and secure maritime transport is one of the main pillars of sustainable development with a poverty reduction approach by providing access to basic goods for nations [8].

One of the major threats to food security and achieving a sustainable food chain is illegal fishing. Since fish is one of the main sources of food for most people globally, illegal fishing is an important obstacle to ending hunger, a serious threat to the protection and sustainability of the marine environment, and the livelihood of fishermen who work legally [8].

The formulation and implementation of laws to reduce the emission of harmful gases is another IMO move that is taken to achieve a sustainable environment and is very effective and vital for communities' well-being, especially in coastal areas and cities. One of these decisions is implementing the Convention on the Reduction of Sulfur in the Fuel Oil Consumption of Ships, which has been implemented since the beginning of 2020 and has affected the health and lives of coastal residents through environmental protection [8].

Since achieving the concept of sustainability in all its dimensions requires comprehensive education by providing equal opportunities for all nations of the world, the IMO also develops the necessary standards in the form of an international convention on seafarers' training, not only added on transport safety marine but also in all stages of training, it has emphasized on environmental protection and safety at sea [8].

From the perspective of gender equality in education, the IMO view is formed to provide job opportunities by empowering and facilitating education for women. The IMO believes that women's activities alongside men in various maritime industry sectors contribute to the development, productivity, and economic growth of communities [8].

Due to fact that achieving a sustainable society without access to clean water and sanitation, as the most vital element of human needs, is difficult or impossible, the IMO has emphasized the management of ship waste and the prevention of waste disposal at sea, intending to preserve water resources and prevent water pollution. The London Convention can be considered the most effective IMO guideline that has been developed in this regard [8].

One of the most important and effective IMO projects being implemented in partnership with the United Nations Development Program and the Global Environment Facility is to focus on the participation of all countries and the use of all regional and trans-regional capacities for marine energy efficiency, and supports carbonation programs and companies active in this field [8].

This capacity building, in addition to improving energy efficiency in the marine industry, is also emphasized in the Climate Mitigation program and is actively pursued and supported through various projects with the support of developing or less developed countries. . This support is provided through synergy and international partnership to facilitate access to new technologies in clean fuels, optimize energy consumption, attracting investment to develop energy infrastructure and transferring technical knowledge related to renewable energy [8].

Providing job opportunities for sustainable economic growth is one of the IMO's focuses on achieving sustainable development goals. The need for seafarers is obvious as a basic element in the maritime industry. Attention to working and living conditions, social security, and their problems are at the forefront of what the IMO emphasizes[8].

IMO support for sustainable economic growth is not limited to the shipping sector. Participate in the development of port infrastructure, pay special attention to creative and innovative technologies, extract energy from marine resources, promote the maritime tourism industry, support fisheries and maritime security, among other IMO-supported sectors, in order to strengthen and contribute to economic growth all nations nationally, regionally and globally [8].

Other global contributions that the IMO emphasizes in achieving the goals of sustainable development, and which has adopted an important strategy so far, are the development of protocols and implementing laws in various

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sectors of the maritime industry to reduce greenhouse gas emissions, and support Practical and ambitious methods in stopping and combating climate change caused by the maritime industry [8].

Protecting the resources of the oceans and seas, through conventions related to the prohibition of waste disposal at sea, noise pollution caused by ships traffic, preventing the transfer of harmful marine organisms by the water of ballast tanks of ships, and improving the safety and quality of shipbuilding and navigation are other important issues that the IMO is committed to, as the highest decision-maker in the maritime industry [8].

Contributing to the development of maritime education institutions, to strengthen the scientific strength of countries and prepare regulatory regimes on shipping issues by training experts in this field is another support coverage that the IMO is committed to and knows it an important part of the sustainable development process with the approach of peaceful development of societies [8].

IMO's extensive cooperation with a wide range of projects, the private sector, and environmental centers, has the potential to enable this international organization to achieve the goals of sustainable development and the development of innovative methods, both in education and in the fields of provides design, construction, the safety of ships and optimization of ships' energy consumption [8].

A research published by the European Commission on sustainable maritime transport with an environmentally friendly approach to port activities emphasized the need to encourage operators who meet approved environmental standards in all their activities to reduce greenhouse gas emissions and energy optimization. According to this plan, which has been implemented in many European ports since 2011, ships that use methods and fuels to reduce emissions can pay lower port costs as a reward [5].

In a study in Norway, it has been pointed out the importance of governments' role through the actions of sustainable development in the maritime industry. According to this research, the government can achieve sustainable development goals by formulating specific programs and strategies and investing in infrastructure based on the development of zero-emission solutions in the maritime industry, with a special look at Innovative Solutions [10].

Intelligent transportation, automated ships, and the use of alternative fuels, such as hydrogen, biogas, battery, and natural gas, are among the possible solutions in this study. Also, synergism in the participation of public and private sectors, by providing a suitable platform for research on creative projects, using research and training institutions' capacity, can accelerate this process [10].

As one of the most important companies in the field of maritime transport, Maersk Shipping Company intends to reduce its carbon dioxide emissions by 60% in 2030 compared to 2008 and onwards, reduce gas emissions to zero by 2050. To achieve this strategy, Maersk focuses on working with all stakeholders to develop the policy and framework needed to achieve this goal and sustainable shipping in line with the goals of sustainable development[11].

In line with sustainable development goals in terms of economic growth and environmental protection, Maersk Company is moving in the direction of active participation through investment and creating opportunities in the ship recycling industry in its organizational strategy. Reducing inequality by providing the same job opportunities by creating an inclusive culture, along with gender diversity at different organizational levels, is a key element in the company's commitment to achieving sustainable shipping[11].

The installation of scrubbers system in the company's fleet and the use of fuel with low sulfur content have been done according to international laws and to reduce air emissions. In this direction, the company is actively involved in meeting the goals of sustainable development in human health and environmental protection by investing and supporting solutions to reduce air emissions [11].

Preserving the oceans' health and life as a great natural heritage for human beings is another issue of concern to this company. The importance of the seas' life is so vital that a large part of this important human resource in providing a livelihood for the people of the world is exposed to various threats from various aspects [11].

The most critical threats to marine life, which is growing at an alarming rate, is the influx of large amounts of plastic waste into the seas. Strict implementation of regional and international guidelines regarding ballast water and waste management system, support, and close cooperation with companies active in ocean cleaning and ocean science research centers is what Maersk company pursues the health of the seas [11].

Free transportation for health services, with the support of Mercy Ships, for sustainable welfare and health, reducing economic gaps, and providing a platform for underdeveloped countries, is an approach taken by the Mediterranean Shipping Company as part of its sustainable development goals. Providing voluntary logistics services, financial support, and voluntary services in various fields, in natural disasters in different countries, and across borders are other supports that this company provides along the sustainable development path [14].

Gender equality in order to eliminate discrimination and create equal opportunities for women in various sec-

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tors related to the company's activities is also emphasized in the company's annual report on sustainable maritime transport [14].

Important decisions and programs identified in the MSC Annual Report include partnership in the development of the ship recycling industry, improving waste management, minimizing the destructive environmental impacts caused by this industry,improving the quality of workers' education, and pay attention to health status. The continuous and sustainable staff training Program is another key and prominent item in its programs, including onboard staff and onshore personnel [14].

Providing the necessary facilities for sustainable water management in various places and providing access to clean water by modern and reliable treatment systems are other projects that MSC has implemented in different parts of the world, and intends to develop and implement it elsewhere based on its sustainable development plan. Investment in robotics and automation in Antwerp's port to reduce emissions, installation and operation of wind turbines to generate electricity, optimize water consumption. Intelligent separation and recycling of waste in this port, are among the methods used to increase sustainability in the port, which is intended by the company [14].

The challenge of climate change resulting from traditional transportation and finding solutions that can respond to climate change is another requirement for sustainable development that MSC has invested in. An example of this investment is in the installation of equipment and finite element modeling in container terminal cranes in some ports, which can lead to improved performance in a wider range of air temperature changes and increase the stability of cranes by installing water tanks in the lower part of the crane structure and thus reduce its center of gravity. These cases greatly help the crane structure resistance in bad weather conditions and natural disasters such as earthquakes and improve ports' sustainability [14].

Utilizing of various technical solutions such as making changes and modifications in bow, rudder, and propeller, on-line and continuous monitoring of the ship's hull in terms of cleanliness, using anti-fouling paints, increasing the carrying capacity, installing the necessary equipment for cold-iron, the use of the air lubrication system is part of the measures that the company has taken to optimize energy consumption and reduce emissions in its active vessels and projects under construction [14].

In 2018, a program was formed to aim the synergy of global leadership to achieve sustainable development goals in collaboration with the International Association of Ports and Harbors and several major ports in different countries, known as The World Ports Sustainability Program (WPSP).In the energy and climate sectors, projects focus on creative projects to reduce ship emissions in ports, improve port operations, generate electricity from renewable sources, carbon capture methods, and the climate change approach [35].

These projects' priorities are in port call optimization, providing low carbon fuel for ships and supplying electricity to ships from land through renewable energy sources to reduce greenhouse gases [35].

In sustainable development goals related to gender equality, health, social responsibilities, and education, various projects are being implemented in ports or are about to be implemented. Allocate a portion of port revenue to develop coastal school infrastructure and improve the quality of health centers in the area, along with women's participation in the maritime industry to empower them, provide scholarships in areas related to port operations, and marine pilots are among the projects outlined in this report [35].

Regarding environmentally friendly and resilient infrastructure, most projects for port sustainability are related to the use of information technology and intelligent systems in improving supply chain and port operations along with meeting the needs of the market and stakeholders through codified planning with a view to development. In this regard, the principle of flexibility in infrastructure development is very important, so that part of this development is related to environmental monitoring using digital methods. The other part is focused on the exchange of information between the port and stakeholders [35].

Most of this program's projects are related to the interaction and development of communication between the port and neighboring cities, which is related to the environmental impacts and social interactions of the ports on the surrounding communities and requires effective communication and participation of both parties in sustainable development. This partnership and interaction are defined in the form of creative initiatives and projects that can meet the needs of the surrounding communities, such as the development of the local economy, the expansion of green areas, and investment in education [35].

Also, environmental considerations arising from the existence of ports and port operations such as waste management, noise, and air pollution, conservation of water resources and ecosystems in the region, in addition to managing ports in accordance with the goals of sustainable development, is another aspect that has been considered in effective participation projects of ports and local communities [35].

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3. Oman Overview- People, Environment, and Economy

Oman is located in Western Asia and has a coast to the north with the Gulf of Oman and the east by the Arabian Sea. Oman's coast reaches more than two thousand kilometers [20]. Oman's population in 2019 is estimated to be around five million, and it is projected to reach over five million by 2020 [25].

In the same year, most of the population is between 25 and 34 years old, whereas the number of males is twice that of females, and 60% of Oman's population are of working age [25]. In the environment, Oman has committed itself to protect the environment by joining almost all international treaties [2]. Oman also has a ministry of environment and climate affairs, which demonstrates the importance of the country's environment [16].

Economically, according to the latest World Bank report, Oman has the highest economic growth in its region. The report expects growth to continue in the coming years with more investment in the upstream and infrastructure industries [30].

4. Background of Oman Maritime Community

Oman has a long history of sailing and shipbuilding due to its long coastlines and is one of the leading countries in this industry. Oman's shipping dates back to over 4,500 years ago, which has been in contact with other countries worldwide, especially India and the countries of North and East Africa. The Omanis have been highly skilled in boat construction and maritime navigation with a well-known port in the world [15].

Its background has long been active in two major maritime areas, namely maritime trade and fishing, and is still one of the most critical industries in the country even today. Archaeological findings at the ports of Oman, which include objects and equipment from China and other countries, indicate antiquity in the country's maritime sector carried out by Oman ships [13].

With its long and significant coastlines, the fisheries sector, as an essential source of food supply, has a long history in the country that caters to local and regional needs [34].

With the expansion of knowledge in the maritime industry, the country is active in other related industries, such as dry-dock, oceangoing ship repair and maintenance and passenger ferries, as well as in the field of maritime trade and fisheries.

In 1989, Oman set up the Oman Fisheries Company to take a significant step towards global markets. In this regard, Oman Fisheries Company established and launched six processing plants with the most advanced equipment and currently exports products to more than 55 countries[21].

Oman Shipping Company was established in 2003 to meet the rapidly evolving needs of the country's industries. With a fleet of natural gas vessels, large oil tankers, chemical tankers, bulk carriers, General Cargoes, and container carriers, the company plays a vital role in Shipping and development. The main approach and purpose of the company are to provide efficient and reliable services to national, regional, and global customers, taking into account the high level of standard and safety, while at the same time taking an exclusive look at environmental protection [26].

One of the active industries in the Oman maritime industry is Oman Drydock, which was established in 2006 to promote modest industrial structure growth. Its services include repairing and converting large ships in various models and are also active in providing services to the oil, gas, and infrastructure industries [18] [19].

In passenger transport, the Oman National Ferries Company (NFC) started operating in 2006 to contribute to the promotion and development of maritime transport, especially in the domestic sectors, and to establish an effective connection between the country's ports [17]. The service provided by the company is not limited to passenger transport, and in addition to scheduled inter-port services, it has been providing dedicated trips since 2008 [17].

5. Local Challenges and Needs

To examine the challenges and needs of marine energy management with what is stated in the Sustainable Development Goals and goal 7, should first review the defined upstream documents and then review the documentation available in the Oman country.

The growing need and increasing demand for energy, as the driving force behind the development, along with population growth and the expansion of industries, are significant challenges in achieving sustainable development goals. This challenge is crucial in balanced growth, consistent and sustained management of the various sectors involved in energy development. Including the sections as follows:

1)Awareness of existing and potential resources.

2)Investigating and calculating the capacity of existing or available renewable and sustainable energy sources.

3)Finding practical and cost-effective solutions to optimally and efficiently use energy resources.

4)A clear plan and roadmap for developing the infrastructure needed in energy management in a coordinated

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and balanced manner.

5)Mobilizing existing national and international facilities for investment in energy infrastructure or optimizing the use of existing resources.

6)Human resources training, and skilled people, to manage energy or operate new systems.

7)Investing in research and development, in close cooperation with science and education communities and the industry with governments' participation to facilitate and accelerate it.

8)A passion and interest in applying innovative technologies and techniques with a positive attitude.

Increase partnerships at the national, regional, and international levels, for synergies, overcome the impediments and ultimately use the successful models and designs used in other countries to accelerate sustainable development.

The imbalance, and the uneven growth, in each of the above sectors can pose a new challenge to energy management. Instituting this global resolve, in the form of a national movement, and utilizing all available capacities to encourage and extend this approach through a targeted program in the organizational structure of education and country management, can be a constructive move towards sustainable development.

Other challenges include resistance from organizations or people to change behavior and consumption patterns due to lack of need, lack of transparency towards development goals, and lack of awareness of the need for energy management, low cost of energy consumption, lack of social accountability, in the public and community level [29].

The high initial cost of investment in renewable energy production, especially in countries with oil and gas resources, and low energy prices reduce their tendency to use new energy[29].

Another challenge is the lack of confidence in innovative and modern designs and methods, which create resistance and doubt in the industry body in applying new solutions. Many of these innovative designs and solutions are still in the pilot phase and require further research and development. Meanwhile, only a limited number of countries have done so.

In Oman, the Ministry of Transport and Communications (MOTC), as a standard and related reference, with the International Maritime Organization, and the Oman Maritime Industry, has been working on explaining and updating roadmaps and sustainable plans development goals [23].

Time is also challenging. Over time, the amount of non-renewable and hydrocarbon fuels decreases every day, and their environmental effects deeper and last longer.

Regional threats, internal conflicts, insecurity, and instability of countries, which transmit a large part of countries' ability to cope with these threats, as well as increasing the riskiness of investing in the energy sector and thereby reducing or disabling them in attracting foreign or even domestic investment, is another challenge. Some countries' geographical location, sometimes even unintentionally, may affect these threats, even if they do not play a role in the threats.

The Oman Ministry of Transport and Communications' annual report, released in 2018, outlines the need for efficient and sustainable transport and the development of access at reasonable and cost-effective rates, as set out in the ministry's mission [23].

Next much more comprehensive document on sustainable development goals is the 2019 Supreme Council for Planning (SCOP) report, which has done a thorough review of each of Oman's sustainable development goals.

The study emphasizes the need for all countries to meet and address challenges at the regional and global levels [28]. Among these challenges are fossil fuels and oil, which are essential and influential variables on the economy and global challenges such as the recession in the economy have also been mentioned. Population growth and changing population patterns towards a young and jobseeker are other challenges in the country [28].

The critical programs in this field are optimizing and targeting budgets using energy-saving methods and looking at using environmentally friendly and sustainable models [28]. Changing the oil-based economic pattern, diversifying the economy, decreasing oil dependence and income to reduce the effects of oil prices are among the needs of target countries [28].

Investment issues is other concern, especially the private sector, which was not acceptable due to some legal barriers. It needs laws and procedures that encourage the private sector to invest. The private sector is also one factor contributing to the reduction of unemployment and job opportunities, which is a severe and significant challenge for achieving development goals [31].

Provide supportive policies to attract young people by the private sector or supporting young people to start a business is cited as a solution to this challenge. There is a need for stability in the economy and the growth and development of domestic production while creating new job opportunities and improving policies and laws to facilitate employment, including government goals and programs.

Another point is the training of the skilled workforce needed, given the market need and familiarity with the new technologies, which has led to the establishment of the National Youth Organization in Oman [28]. Oman is

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working to overcome the challenges of achieving goal 7 of Sustainable Development and moving towards renewable energy by developing a clear roadmap called the National Energy Strategy [28].

These include a plan to reduce fifty percent of the gas used in the oil industry and use solar energy as an alternative and sustainable energy by the beginning of 2026 [28]. Other challenging energy topics, the existence, and stability of government subsidies and support, access to gas as an energy source, population growth as a consequence of the growth of energy consumption, and ultimately, the growth and development of industries and increasing energy demand [28].

Regarding renewable energy, this technology's continued use remains a significant challenge, and besides raising professional people who can respond to this new model of energy. Instance of these projects are the "Mirra" project, which has replaced gas consumption in one of the Oman oil fields by using solar power generation and generating more than 1,000 megawatts of electricity [28].

Oman, given the International Maritime Organization's acceptance of its regulations, as its principal source of industry, is bound to enforce these rules. Therefore, it can be said that the implementation and adherence to these laws and guidelines are in line with the goals of sustainable development.

Including these rules and regulations are guidelines for the Ship Energy Efficiency Management Plan (SEEMP) to reduce fuel consumption and reduce pollution [7]. Besides, guidelines for the Energy Efficiency Design Index (EEDI) required for the construction of new vessels are also included in the plans used for marine energy management [7].

In 2019, the Oman Shipping Company ordered the construction of three very large oil tanker vessels at the Daewoo Shipbuilding Company in South Korea. Important and essential in this order is the eco-friendliness of these ships and the new generation of this class of ships [24].

In the matter of ships and vessels other than those required by the IMO guidelines, and shipping companies required to implement it, no report or solution was found, especially on renewable energy use. In 2019, an international conference on marine engineering and technology was organized by the Oman Military College of Technology. It covered various chapters, including optimizing fuel consumption and using renewable energy in the maritime industry [6].

Such approaches can, in addition to driving existing national and international capacities toward an acquaintance with modern knowledge or innovative designs and solutions, plays a vital role in the synergies and active partnerships between the various sectors of the industry, especially in relation to scientific and industrial centers, and in line with development goals.

Concerning the training of expert and knowledgeable staff, familiar with the issues of energy management, the Ministry of Transport and Communications of Oman has emphasized that the manner of issuance of documents is based on Seafarers' Training, Certification and Watchkeeping standards and as a result, people should be thoroughly familiar with the rules and guidelines of the International Maritime Organization, including the objectives of sustainable development, increasing efficiency, and energy management [23].

It seems that professional development is not limited to people working in the fleet.

About energy management, there is also a need for people capable of policy and decision making and be familiar with economic, environmental issues and safety, requiring a plan to train these people and to use them to improve energy management and energy consumption [22].

What seems to be critical here is the focus solely on the technical aspect of energy efficiency management. This concentration has focused on the specific design considerations when building a ship and implementing a supervisory and management system on energy use, especially of the fleet[9].

This point of view can be led to other issues being overlooked or even neglected aspects and topics such as the workforce's role or even gender in energy efficiency management [9].

6. Analysis by Using Five P's of Sustainable Development

This section examines the role of key players in Oman's maritime industry including, Oman Fisheries Company and Oman Shipping Company, in five key areas and indicators in sustainable development goals, including people, planet, peace, prosperity, and partnership.

Achieving sustainable development goals in the maritime industry will certainly not be achieved unless all stakeholders are directly or indirectly involved. Where sustainable development goals are accepted, in the form of a blueprint, including a set of goals designed in different parts, synergy and stakeholder engagement can be very useful because of the shared purpose.

6.1 People

As an essential part of the food chain, fisheries play a vital role in maintaining healthy nutrition and reducing hunger. Oman Fisheries, both domestically and regionally and internationally, have been instrumental in reducing

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hunger by having a significant market share of fish and related products. The emphasis on food and health under its goals reflects its commitment to public health. Providing healthy, appropriate, and quality food is one indicator of a sustainable society [21].

One of the hallmarks of any underdeveloped country can be the country's high poverty rate. As a result of inadequate explanations of wealth, class distinctions and gap, and lack of access to adequate food, growing poverty is moving towards deepening.

Key factors in reducing poverty are provided equal opportunities and creating appropriate employment opportunities, and the abundance and availability of adequate food. Oman Fisheries have helped significantly reduce poverty rates both domestically and internationally, by providing a suitable environment for the supply and distribution of sufficient food, both for domestic consumption and to meet some international food needs [21].

The Oman Shipping Company has been instrumental in expanding domestic trade and creating new job opportunities by creating a secure business route and expanding trade internationally [26].

The expansion of commerce has enabled the expansion of the logistics and commerce sector, industries, and related small businesses. The development of roads, residences, warehouses, out-of-doors restaurants, repair shops, and even the development of these required training centers are only part of this activated chain. In other words, the activation and expansion of Shipping, both directly and indirectly, can lead to sustainable development.

6.2 Planet

The Oman Fisheries Company considers itself responsible for the conservation and protection of the environment and the prevention of pollution of the seas. This company has also allocated a portion of its profits to the marine environment and upgraded its safety knowledge. The company focuses on preserving the marine environment and clean water, focusing on preserving marine resources and healthy food. In the company's vision, the emphasis is on the sustainability of the fisheries' environment [21].

The country approved and implemented a law prohibiting trawl fishing in 2011 to protect the marine environment and its resources [34].

As stated, in 2019, the Oman Shipping Company ordered the construction of three very large tanker vessels to the Daewoo Shipbuilding Company [24]. A few months later, the company commissioned two more eco-friendly tanker ships with the Daewoo Shipbuilding Company [27].

What was highlighted in these orders was the emphasis on environmentally-friendly, eco-friendly, which demonstrates the company's strong commitment to protecting the environment through modern shipbuilding technologies. The company also emphasizes the strict implementation of International Maritime Law and Regulations in marine environment protection as a committed member of the global maritime community [26].

6.3 Peace

One of the most critical indicators in the field of peace is the security in that community. The security of each community reflects people's attitudes in societies in the field of ethical, social, and economic indicators. Poverty, unemployment, and illiteracy are threats to any country's security that can lead to instability and conflict and are one of the biggest obstacles to sustainable growth.

Oman's Fisheries Company has had a significant impact on the development of peace by affecting various sectors and ways of affecting the country's security. Creating job opportunities and sustained employment has reduced the poverty rate and, as a result, increased community mental health and well-being. Also, proper and healthy nutrition has enhanced security [21].

The development of a skilled and efficient workforce, which contributes to the growth of literacy and expertise, has added to the promotion of security and, ultimately, sustainable peace. One of the goals of Oman Shipping Company is to provide safe and reliable service to all customers [26].

Due to the volume of cargo movement and other required products of the country, which is mostly done by the company's fleet, it has had a significant impact on supplying the country's people with needs in the field of import and export, as well as providing economic security for the people. Oman Shipping Company is one of the most active companies in sustainable peace.

6.4 Prosperity

The Oman Fisheries Company has been able, by employing a large number of young people, to play an important role in reducing the unemployment rate and thereby increasing people's well-being [21].

The existence of this industry and the creation of a distribution chain have created many jobs, directly and indirectly, in the field, leading to increased levels of public welfare [21]. On the other hand, with the optimization of this trade and new technologies in the production and supply of fishery products, energy consumption has improved and decreased compared to traditional systems.

Also, the reduction of energy consumption and the use

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of new technologies have reduced the price of finished goods and, consequently, increased the people's purchasing power, which is a move forward in the sustainable prosperity of the people [26].

The Oman Shipping Company has a well-planned program to recruit labor from the Omani youth. This job is equally available to all, regardless of gender [26]. Providing these enduring job opportunities enhances happiness and ultimately sustained prosperity.

Oman Shipping Company has provided a scholarship to those interested in studying marine engineering and nautical science. In addition to its support for the maritime industry, the company has also provided an opportunity for undergraduates to pursue an internship on the company's fleet [26].

This excellent performance has not only increased the sense of hope and satisfaction among young people but has also made a positive step towards achieving sustainable development goals.

6.5 Partnership

The Oman Fisheries Company has one of the best partnership models in sustainable development with the granting of shares to fishers. This decision led them to increase their level of responsibility as they participate in fisheries. The company is also a reliable trading partner for other countries by exporting fish and other fishery products to more than 55 countries. Considering part of its profits in creating new job opportunities for fishermen, coastal women, and new markets, it has also increased the level of participation at the domestic level [26].

The Oman Shipping Company is moving towards sustainable development by providing the appropriate infrastructure and facilities needed by domestic, regional, and international maritime transport industries. This partnership encompasses a wide range of industries. The Oman Shipping Company is equipped with its maritime fleet, in various maritime shipping areas, including tankers, containers, bulk carriers, General Cargoes, and chemical tankers; it has been able to play a unique role in the development and stability of this partnership by providing safe and orderly services [26].

Key partners in domestic supply include the Orpic Company (the largest petrochemical company in Oman), Sohar Aluminium, and Oman LNG Company. Regional offerings include Indian Sail Company active in Steel Trading and internationally includes Shell Oil Co., BP Oil Co., and Brazilian Vale Company active in Mining Trading [26].

7. Conclusions

In studying the marine industry of Oman, in line with Sustainable Development Goal # 7, and the five relevant and influential areas of this document, namely the people, the planet, peace, prosperity, and partnership, seem to be a distinct and well-structured program at different levels that demonstrates national determination in the right direction towards development goals.

Sectors and stakeholders of the country's maritime industry are moving alongside each other in pursuit of these goals, along with the synergy and overlap, which is a good sign of achieving sustainable development goals.

Meanwhile, some areas and sectors of the maritime industry that have the potential to achieve sustainable development goals have not been addressed. Among these areas can be mentioned, ocean energy, aquaculture, coastal tourism, marine biotechnology, renewable energy use in ports and ships, deep-sea mining.

On the other hand, annual and documented reports that specifically address sustainable development goals have not been published by companies involved in the maritime industry. These reports can lead to precise targeting, benchmarking, analysis of current conditions, and explaining new strategies and ways to move smarter on the path to development goals.

One of the appropriate approaches in sustainable development could be modeling plans and methods being implemented by other countries.

Finally, although Oman is on the right track towards development goals, it can accelerate and create effective solutions by focusing on new technologies and innovative designs and more productive industry linkages with science centers.

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ARTICLE

Analysis of Some Elements and Speciated Compounds in Fish Found in the New Calabar River of the Niger Delta Area, Nigeria

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ABSTRACT

The flesh of guinean and blackchin tilapia, and mullet found in Choba river were collected for elemental studies of mercury, cadmium, lead, arsenic, nickel and speciated forms. Analytical method of X-ray fluorescence (XRF) was used for the elemental studies while Gas chromatography-mass spectrometer (GC-MS) was used for the speciated forms. 4.3 mg/kg was the highest concentration of cadmium observed in blackchin tilapia. The three fish species all contained about 0.5 mg/kg of arsenic and 1 mg/kg of mercury. 1.7 mg/kg of lead was detected in mullet while 7.3 mg/kg of nickel was detected in blackchin tilapia. Organometallic compounds found were nickel tetracarbonyl, borane carbonyl in guinean tilapia, nickel tetracarbonyl, borane carbonyl and germanium(iv) pthalocyanine dichloride in blackchin tilapia and [μ-(η6-benzene)] bis (η5-2,4-cyclopentadien-yl) di-μ-hydrodi-vanadium. Borane carbonyl was found in mullet.

1. Introduction

Elements like mercury, arsenic, lead and cadmium are well-known to have major human health problems [1]. Cadmium inhibits membrane-bound enzymes [2]. Cadmium complexes with sulphydryl groups in the active sites of enzymes. Research has shown that these complexes can hinder the formation of enzyme-substrate complex [3]. Research has also shown that using dithiothreitol (DTT) for the treatment of cadmium toxicity is better than other methods since it serves as a chelator and also restores the sulphydryl groups [4]. It is well documented that people ingest arsenic and other toxic metals mainly through food such as poultry, rice, mushrooms and seafood [5,6,7,8].

Mercury through microbe bio-transformation in fishes can form methylmercury (MeHg). Some researchers have reported that the accumulated form in fish are in many cases extremely high compared to the surrounding water [9]. MeHg is known to be toxic and that it can also accumulate in the food chain [10]. MeHg can be consumed through fish consumption. If MeHg is found in animals it is usually in the organs like kidney, liver, nervous system and prenatal

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life where it exhibits its toxicity [11]. High lead concentration can reduce aquatic population of mussel [12]. Potato peel is prone to heavy metal accumulation [13]. Thus, it should be removed before consumption. For a similar reason, this is why the amount of leafy vegetables eating in a day should be limited. The presence of high concentrations of nickel in animals can lead to retarded growth and development [14]. Elements exists in various forms. While some these forms are toxic, others are not [15]. The essence of this work was to shed light on the concentrations of these toxic elements since people depend on this river for their source of fish and to also determine the speciated forms in these three fish species.

The exact quantity of these toxic elements present in the fish consumed from rivers around the Niger Delta region is not well documented. This research work sheds light on this.

2. Location, Materials and Methods

2.1 The Study Location

The arrow in Figure 1 shows the sampling site. This river is located between longitude 6°53.95E and latitude 4°53.78N [16]. It is in Choba village. Close to it is an extension of Wilbros Nigeria Limited (WNL), an oil Servicing Company.

Figure 1. Location of Choba river

2.2 (a) Sampling and the Preparation of the Sample for X-ray Fluorescence

Table size fresh samples of the three fish species were taken from the river (Figures 2,3,4). After cleaning, they were wrapped in an aluminum foil and then put into ice. Finally, they were put in a black polyethylene bag and then all in a cooler to the laboratory for analyses.

Figure 2. Guinean Tilapia

Figure 3. Blackchin Tilapia

Figure 4. Mullet

2.3 X-ray Fluorescence Analysis and Quality Control

The concentrations of the elements were done with X-ray fluorescence spectrometer. This was done in accordance with the USEPA 6200. The drying of the fresh fish samples was done in the oven and it was at 110°C and for twenty hours. The edible fleshy part of the fresh fish samples were reduced to lower than 2µm diameter through crushing. Then, pulverized. They were further made into pellets, moved into a prolene foil that was already cleaned and then put into sample vial. They were then labelled

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accordingly before arranging them in the sample tray. Finally, they were taken to the compartment for sample in the X-ray fluorescence equipment (SpectroX-LabPro) for their elemental composition determination. Through previously stored calibration and with a certified reference material the elemental concentrations of the samples were deduced. The source of excitation was X-ray tube (synchrotron). The matrix effect was corrected by the appropriate means. The sample was analyzed several times to check reproducibility.

2.3.1 GC-MS Analysis

This involved 2 stages. Stage one was extraction while stage two was derivatization just before chromatographing.

Scales were removed first from fish using a ceramic knife as specified by IUPAC [17]. Then the cutting of the edible part was done using the ceramic knife. Mortar and pistol were used homogenizing. 2g of homogenized fish sample was collected and 5ml of 20% TMAH was introduced to digest it. It was then taken to a water bath at the temperature of 60^{o}C where it remained for 2 hours. At the end of the 2 hours pH was checked. It is important that the pH remains between 6-8. 3ml of 0.5M NaDDTC was added. 1.5ml of both toluene and benzene were then added. It was then agitated for 2hrs in a mechanical shaker.

For the 2nd stage, a large balloon was filled with pure nitrogen gas. Then, 5ml of the fish sample which was from the initial stage one was collected with a syringe. The air in the sample was then flushed with the nitrogen gas in the balloon and for several minutes. While the flushing was on, 3ml of n-BuMgCl and 2ml THF were introduced. They were then agitated for 10 mins. In case of the presence of any excess Grignard reagent, 10ml of 0.5M sulphuric acid was added to destroy it. Two phases resulted which were then separated. GC-MS analysis was carried out on the organic phase.

3 Results and Discussion

3.1 Results

3.1.1 X-ray Fluorescence

Table 1 shows the concentrations of elements in the three fish species

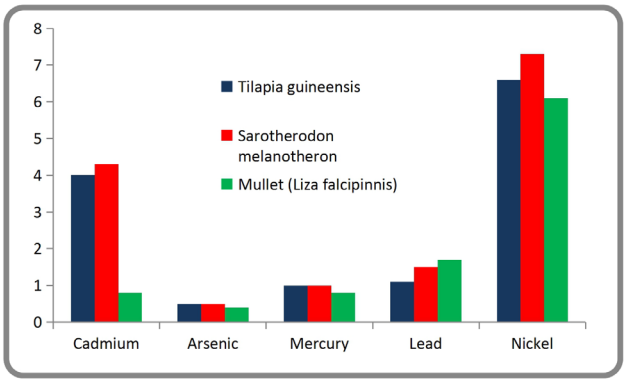

Figure 5. Concentration (mg/kg) of cadmium, arsenic, mercury, lead and nickel in the three fish species

3.1.2 GC-MS Analysis Chromatogram

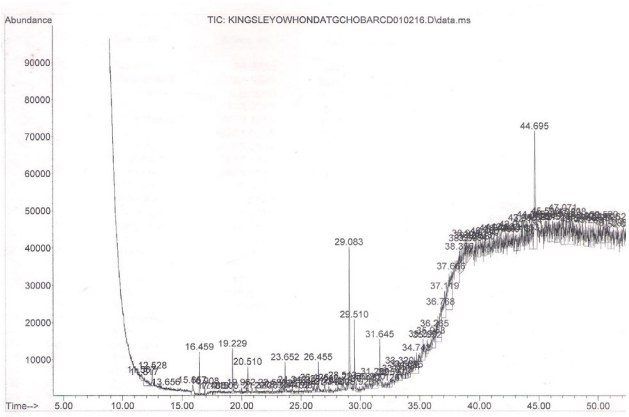

Figure 6. Chromatogram of *Tilapia guineensis* from Choba river

Table 1. X-ray fluorescence analysis result

Fish Specie	Cd(mg/kg)	As(mg/kg)	Hg(mg/kg)	Pb(mg/kg)	Ni(mg/kg)
Guinean Tilapia (Tilapia guineensis)	4.0	0.5	1.0	1.1	6.6
Blackchin Tilapia (Sarotherodon melanotheron)	4.3	0.5	1.0	1.5	7.3
Mullet *(Liza falcipinnis)*	0.8	0.4	0.8	1.7	6.1

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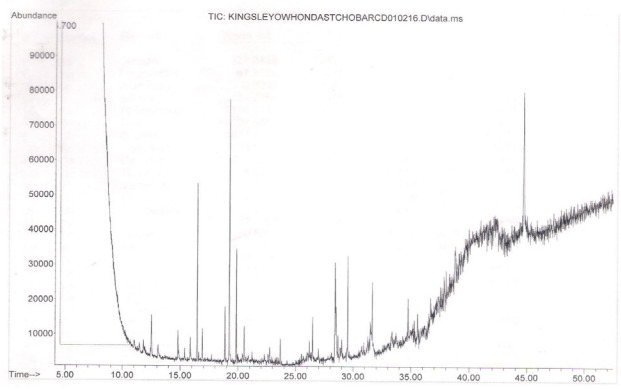

Figure 7. Chromatogram of Sarotherodon melanotheron from Choba river

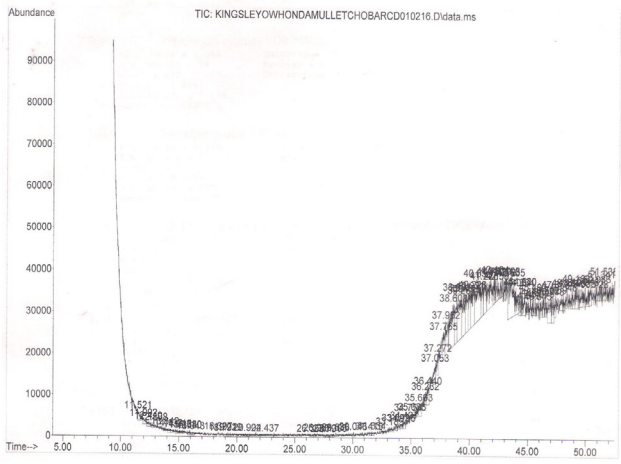

Figure 8. Chromatogram of Mullet (Liza falcipinnis) from Choba river

3.2 Discussion

3.2.1 Cadmium

The cadmium detected was 0.8-4.3mg/kg. Cadmium is known to exerts toxic effect on kidney and body systems. Thus, it has been classified as a carcinogen [18]. It is also known to accumulate in many organisms including crustaceans and molluscs. Vegetables, cereals and starchy roots have shown lower concentrations [19]. Safe amount of cadmium in a month is 25µg/kg body weight [19].

3.2.2 Arsenic

The arsenic detected was 0.5mg/kg or less. The tolerable limit for arsenic in food is yet to be established [19,20]. Thus, the quantity of these fish species consumed per day should be in moderation.

3.2.3 Mercury

For mercury, 1.0mg/kg or less was detected. MeHg was not detected. Research shows that mercury is toxic to humans no matter the form in which it is found [21]. It is even more so to the developing foetus in the uterus and its early life. This is because mercury damages the brain, the lungs and the kidney. 0.5-1mg/kg is recommended as safe limits [22].

3.2.4 Lead

The lead detected was 1.1-1.7mg/kg. There is no known safe level [23].

Table 2. Speciated forms of elements detected in the three fish species

Type of fish	Compound detected	Retention time (minutes)	Amount (%)
Tilapia guineensis	Nickel tetracarbonyl	4.51	8.11x10-3
	Borane carbonyl	5.46	3.36 x10-4
Sarotherodon melanotheron	Nickel tetracarbonyl	4.75	5.41 x10-1
	Borane carbonyl	6.69	3.07 x10-4
	Pthalocyaninedichloridegermanium	44.68	8.20 x10-3
Mullet *(Liza falcipinnis)*	Borane carbonyl	6.42	2.06 x10-4
	[µ-(η6-benzene)]bis(η5-2,4-cyclopentadien-yl)di-µ-hydrodi-vanadium	34.74	1.55 x10-4

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3.2.5 Nickel

The nickel detected was 6.1-7.3mg/kg. 5-50µg of nickel is required per day. While 4.2µg of nickel per kg body weight in a day come from food [24] an upper limit of 1mg of nickel in a day for adults from all sources has been indicated [25].

Nickel tetracarbonyl is an organonickel compound. It is the main carbonyl compound of nickel. It is a pale-yellow liquid with the formula $Ni(CO)_4$ and is extremely poisonous. It is fatal if absorbed through the skin or even when inhaled [26]. The LD_{50} concentration is 3ppm. For humans, the fatal dose remains 30 ppm. This is because the half-life of $Ni(CO)_4$ is just 40s and so, it can decompose very quickly in air [23]. As a result, it will not cause harm when ingested through fish consumption.

4. Conclusions

The results did show that the fish species contain toxic elements. It showed that the quantity of these toxic elements present depend on the type of fish and the river in which it is found. However, the result also suggests that their toxicity may well depend on the quantity of the fish consumed and the totality of all food sources that contain these toxic elements that are consumed daily.

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Cadmium, cadmium chloride, cadmium oxide, cadmium sulphide, cadmium acetate, cadmium sulphate. Geneva, World Health Organization, pp.1075-1318.

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ARTICLE

Spatio-temporal Variability of Dinoflagellates in Different Salinity Regimes in the Coast of Rakhine

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ABSTRACT

Regarding the spatial and seasonal variations of dinoflagellates in different salinities regimes, *Prorocentrum rostratum* showed a strong correlation with high salinity (≥ 29 ppt.). However, *P. micans* had a negative correlation with salinity. In Dinophysoids, *Dinophysis caudata* showed a wide salinity tolerance than other species in the group. *D. miles, Ornithocercus magnificus, O. steinii*, and *O. thumii* showed a strong correlation with salinity. In Gonyaulacoids, *Ceratium furca, C. fusus, C. horridum, C. trichoceros, C. tripos, Gonyaulax polygramma, G. spinifera,* and *Pyrophacus magnificus* showed a strong correlation with salinity. In Peridinoids, *Protoperidinium depressum, P. oblongum, P. oceanicum, P. pyreforme,* and *Podolampus palmipes* showed a strong correlation with salinity. In Gymnodinoid and Noctilucoid, *Gyrodinium estuariale* and *N. scintillans* showed a strong correlation with salinity.

1. Introduction

Dinoflagellates are important components of the phytoplankton in the near-shore and continental shelf environments [1]. Along with diatoms, over half of dinoflagellates are photosynthetic [2,3,4]. Their ecology and biology have permitted them to be among the most successful aquatic protists, capable of surviving in different conditions of resource availability [5,6]. They are one of the major groups of primary producers that constitute the basic source of energy in aquatic food webs [7,8]. Because of the annual variability in species composition of dinoflagellates, these species are regularly monitored in many developed countries. In Myanmar, however, has not yet set effective monitoring programs, though there are reports of some bloom events that had been occurred in the coastal area. Since the South-West Monsoon (SWM) is the main source of climatic variations subjected to make changes in the physicochemical parameters which in turn affecting dinoflagellate community structure in the water column [9,10]. Thus, observations on salinity and species occurrence of dinoflagellates were made monthly during three consecutive periods 2012, 2013, and 2014.

2. Materials and Methods

2.1 Environmental Parameters of the Study Area

The Rakhine coast experiences intense rainfall during

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the monsoon months of June-September causing variations in salinity ranges. During the summer season (February- May), salinity was higher (32-34 ppt.) in all stations, and the lowest salinity range, 21-23 ppt. is in the rainy season, (June-September).

2.2 Sampling Sites and Sample Collection

A total of eight sampling sites were set along the Rakhine coast. Sampling sites were plotted at Wetthe (WTE) (N17º 08´ 34.474", E94º 27´51.226") as station-1; MaGyi tidal creek (upper) (MGU) as station-2; MaGyi tidal creek (lower) (MGL) as station-3; MaGyi coastal area (MGC) as station-4; Kyauk-Maung-Nama (KMN) as station-5; Phoe-Kala Island (PKI) as station-6; Ngwe-Saung (NSG) as station-7 and Chithu Island (CTI) near Ngwesaung beach (N16º 49´6.243", E94º 23´8.757") as station-8, respectively. Among the stations, stations 2, 3, and 7 are in and near the tidal creek; stations 1, 5, and 8 are in the open coastal areas and stations 4 and 6 are at the mouth of the tidal creek.

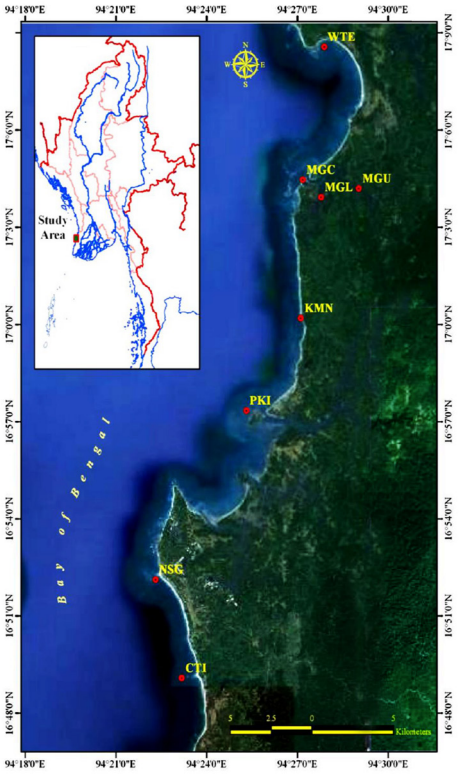

Figure 1. Sample collection sites at Rakhine coastal waters.

The sample collection was made by scooping a known volume of surface water using a basket and sieved with a 20 µm mesh phytoplankton net. Then transferred the water sample to the plastic bottles and immediately fixed it with formalin (final concentration 1%). While collecting the samples, water salinity was measured *in-situ* with a refractometer. Triplicate analysis of 1 mL sub-sample was taken from the samples and count with the Sedgwick-Rafter chamber. Pearson's correlation coefficient was performed to analyze the relationship between dinoflagellate species and the salinity.

3. Results and Discussion

3.1 Seasonal Variations of Salinity

At station 1, WTE, the highest salinity occurred in late summer, March-April, and the range was 34 ppt. in 2012; 33 ppt. in 2013 and 32-33 ppt. in 2014. During the monsoon period, July to September, salinity reaches its minimum values, 25-26 ppt. in 2012; 23-24 ppt. in 2013 and 23-25 ppt. in 2014. Mean salinities were 29.6±3.1 in 2012; 28.25±3.65 in 2013 and 28.5±2.87 in 2014.

At station 2, MGU, the highest salinity occurred in late summer, March-April, and the value was the same 30 ppt. in three successive years, 2012, 2013, and 2014. Station 2 has highly fluctuated with terrestrial runoff. During the monsoon period, July to September, salinity reaches its minimum values, 13-16 ppt. in 2012; 13-19 ppt. in 2013 and 13-18 ppt. in 2014. Mean salinities were 22.92±5.79 in 2012; 23±5.24 in 2013 and 22.75±5.48 in 2014.

At station 3, MGU, the highest salinity occurred in late summer, March-April, and the values were 29-32 ppt. in 2012; 32 ppt. in 2013 and 2014. During the monsoon period, July to September, salinity reaches its minimum values, 25-24 ppt. in 2012, 2013 and 24-25 ppt. in 2014. Mean salinities were 27.92±2.84 in 2012; 28.2±2.91 in 2013 and 28.2±3.1 in 2014.

At station 4, MGC, the highest salinity occurred in late summer, March-April, and the values were 33-34 ppt. in three successive years, 2012, 2013, and 2014. During the monsoon period, July to September, salinity reaches its minimum values, 25-26 ppt. in 2012, 22-24 ppt. in 2013 and 23-25 ppt. in 2014. Mean salinities were 25.50±5.77 in 2012; 26.25±5.00 in 2013 and 23.93±6.24 in 2014.

At station 5, KMN, the highest salinity occurred in late summer, March-April, and the values were 29-32 ppt. in 2012; 32 ppt. in 2013 and 2014. During the monsoon period, July to September, salinity reaches its minimum values, 18-21 ppt. in 2012, 24-22 ppt. in 2013 and 25-24 ppt. in 2014. Mean salinities were 26.7±5.68 in 2012; 27.83±3.98 in 2013 and 28.08±3.04 ppt.in 2014.

At station 6, PKI, the highest salinity occurred in late summer, March-April, and the values were 34 ppt. in 2012; 2013 and 2014. During the monsoon period, July to September, salinity reaches its minimum values, 26-24 ppt. in 2012, 26-23 ppt. in 2013 and 26-25 ppt. in 2014.

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Mean salinities were 29±3.81 in 2012; 29±3.51 in 2013 and 29.58±3.55 ppt.in 2014.

At station 7, NSG, the highest salinity occurred in late summer, March-April, and the values were 32-33 ppt. in 2012; 33-34 ppt. in 2013 and 34 ppt. in 2014. During the monsoon period, July to September, salinity reaches its minimum values, 26-25 ppt. in 2012, 2013 and 28-27 ppt. in 2014. Mean salinities were 29±3.19 in 2012; 29.33±3.22 in 2013 and 30.58±2.63 ppt.in 2014.

At station 8, CTI, the highest salinity occurred in late summer, March-April, and the values were 32-33 ppt. in 2012; 33-32 ppt. in 2013 and 32-33 ppt. in 2014. During the monsoon period, July to September, salinity reaches its minimum values, 27-26 ppt. in 2012, 26-25 ppt. in 2013 and 24-25 ppt. in 2014. Mean salinities were 29.42±2.6 in 2012; 29.17±3.02 in 2013 and 28.58±3.55 ppt in 2014.

In the present study, the mean salinities of the study period, 2012-2014, were 29 ppt., 27 ppt., 28 ppt., 30.3 ppt., 30.1 ppt., 29 ppt., 30 ppt., and 29 ppt. at stations 1, 2, 3, 4, 5, 6, 7 and 8 respectively. Salinity distributions in all sampling stations vary from month to month within seasons (Table 1). The mean salinity of the whole study area was 29±2.83, and the mean salinity at the sampling stations was 29±1.2 part per thousand.

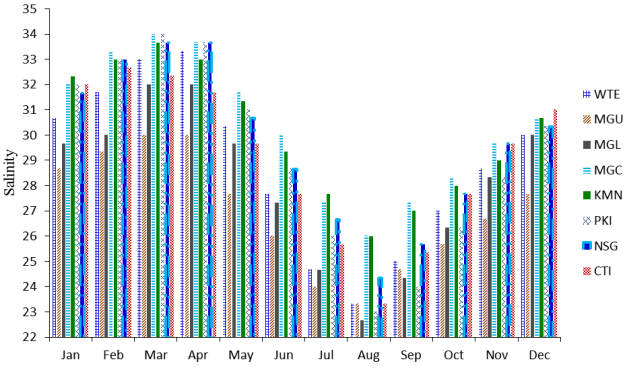

Figure 2. Mean salinity at sampling stations of the study areas during 2012-2014.

3.2 Spatio-temporal Variations of Dinoflagellates

Prorocentroids cell density varied from 1500 to 1780 cells L^{-1} during the study period. The cell density of Dinophysoids varied from 810 to 1590 cells L^{-1} during the summer and post-monsoon periods. Two genera such as *Dinophysis* and *Ornithocercus* were mainly composed in the Dinophysoid group which occupied 40% and 60%, respectively.

Gonyaulacoids was the largest and dominant group in the study area, and the cell density ranged from 540 to 1770 cells L^{-1}. A total of six genera were occupied in the

Table 1. Mean salinity of the study area during 2012-2014.

No.	Months	WTE	MGU	MGL	MGC	KMN	PKI	NSG	CTI	*Mean*	*SD*
1.	Jan	30.7	28.7	29.7	32	32.3	32	31.7	32	31.1	1.2
2.	Feb	31.7	29.3	30	33.3	33	33	33	32.7	32	1.4
3.	Mar	33	30	32	34	33.7	34	33.7	32.3	32.8	1.3
4.	Apr	33.3	30	32	33.7	33	33.7	33.7	31.7	32.6	1.2
5.	May	30.3	27.7	29.7	31.7	31.3	31	30.7	29.7	30.3	1.2
6.	Jun	27.7	26	27.3	30	29.3	28.7	28.7	27.7	28.2	1.2
7.	Jul	24.7	24	24.7	27.3	27.7	26	26.7	25.7	25.8	1.2
8.	Aug	23.3	23.3	22.7	26	26	23	24.3	23.3	24	1.2
9.	Sep	25	24.7	24.3	27.3	27	24	25.7	25.3	25.4	1.1
10.	Oct	27	25.7	26.3	28.3	28	26.3	27.7	27.7	27.1	0.9
11.	Nov	28.7	26.7	28.3	29.7	29	28.3	29.7	29.7	28.8	1.0
12.	Dec	30	27.7	30	30.7	30.7	30.3	30.3	31	30.1	1.0
Mean		29	27	28	30.3	30.1	29	30	29	29	1.2
SD		3.2	2.2	2.9	2.6	2.5	3.6	3.0	3.0	2.8	0.2

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Gonyaulacoids group, *Ceratium* 65%, *Gonyaulax* 10%, *Pyrocystis* 10%, *Alaxandrium* 5%, *Spiraulax* 5%, and *Pyrophacus* 5%, respectively.

The Peridinoids cell density ranged from 800 to 1440 cells L^{-1}, in which *Protoperidinium* composed 57%, *Podolampus* 28.6%, and *Peridinium* 14.3%, respectively. The Gymnodinoids and Noctilucoids group had the lowest cell density ranged from 90 to 112 cells L^{-1}. In the study area, the cell density was normally higher during summer and post-monsoon periods when the salinity was ≥29 ppt.

3.3 Statistical Analysis

Multiple correspondence analyses were made for the correlation coefficient of species and salinity changes. Salinity changes may vary from one station to another.

In Table 2, *P. rostratum* showed a strong correlation with high salinity, 29-31 ppt. *P. micans* showed no correlation with salinity. *P. gracile, P. lima, P. micans,* and *P. rostratum* species were not found in station 2 where salinity is low. High cell densities were found normally at salinity, 30-31 ppt. in February-March.

Table 2. Correlation coefficients of Prorocentroids and salinity.

No.	Prorocentroids	2012	2013	2014
1.	*Prorocentrum gracile*±	0.14	0.67	0.60
2.	*P.lima*±	0.16	0.79	0.19
3.	*P.micans*-	0.02	0.34	0.45
4.	*P.rostratum*++	0.72	0.68	1

(++) = strongly correlated, (±) = more or less correlated, (-) = less correlated

Table 3. Correlation coefficients of Dinophysoids and salinity.

No.	Dinophysoids	2012	2013	2014
1.	*Dinophysis caudata*±	0.83	0.41	0.86
2.	*D. miles*++	0.80	0.74	0.79
3.	*Ornithocercus magnificus*++	0.55	0.72	0.84
4.	*O.steinii*++	0.74	0.71	0.99
5.	*O.thumii*++	0.9	0.75	0.57

(++) = strongly correlated, (±) = more or less correlated, (-) = less correlated

In the Dinophysoids group, *O. thumii* species showed low salinity, 23-25 ppt. tolerant than other species in the group. *D. miles, O. magnificus, O. steinii,* and *O. thumii* showed a strong correlation with a wide salinity range, 23-34 ppt. *O. steinii* cannot tolerate low salinity than *O. magnificus* species. *D. caudata* cannot be found in low salinity of less than 22 ppt. (Table 3).

The Gonyaulacoids, the largest and dominant group in the study area, and among them nine species show a strong correlation with a wide range of salinity. They were *Ceratium dens, C. furca, C. fusus, C. horridum, C. trichoceros, C. tripos, Gonyaulax polygramma,* and *G. spinifera,* respectively. *G. polygramma* was found in low salinity, 23 ppt. (Table 4).

Table 4. Correlation coefficients of Gonyaulacoids and salinity.

No.	Gonyaulacoids	2012	2013	2014
1.	Alexandrium concavum±	0.24	0.65	0.05
2.	Ceratium breve-	0.02	0.34	0.45
3.	C. dens++	0.72	0.68	0.67
4.	C. extensum±	0.48	0.41	0.76
5.	C. furca++	0.70	0.92	0.79
6.	C. fusus++	0.65	0.50	0.78
7.	C.horridum++	0.67	0.71	0.66
8.	C.inflatum±	0.48	0.75	0.66
9.	C.lineatum-	0.25	0.49	0.19
10.	C.porrectum±	0.27	0.39	0.53
11.	C.macroceros±	0.53	0.36	1
12.	C.schmidtii±	0.42	0.61	0.69
13.	C. trichoceros++	0.71	0.60	0.93
14.	C. tripos++	0.89	0.75	0.51
15.	Gonyaulax polygramma++	0.65	0.71	0.74
16.	G.spinifera++	0.76	1.0	0.50
17.	Spiraulax kofoidii-	0.44	0.47	0.19
18.	Pyrocystis lunula±	0.08	0.45	0.07
19.	Pyrophacus magnificus++	0.53	0.53	0.67
20.	P.steinii±	0.48	0.40	0.65

(++) = strongly correlated, (±) = more or less correlated, (-) = less correlated

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In the Peridinoid group, all the members of Protoperidinium show a strong correlation with salinity.

Some *Peridinium* were assigned to the genus *Protoperidinium* in some systematic studies. In this study, this species shows less correlation with salinity. The cell density of *Protoperidinium* may vary with salinity changes. Cell density will increase when the salinity increases in the water column. (Table 5).

Table 5. Correlation coefficients of Peridinoid and salinity.

No.	Peridinoid	2012	2013	2014
1.	*Protoperidinium depressum*$^{++}$	0.85	0.62	0.93
2.	*P. oblongum*$^{++}$	0.57	0.53	0.92
3.	*P.oceanicum*$^{++}$	0.51	0.69	0.99
4.	*P.pyreforme*$^{++}$	0.64	0.71	0.62
5.	*Peridinium pentagonum*-	0.24	0.65	-0.04
6.	*Podolampas elegans*±	0.39	0.47	0.77
7.	*P.palmipes*$^{++}$	0.74	0.72	0.93

(++) = strongly correlated, (±) = more or less correlated, (-) = less correlated

In the Gymnodinoids and Noctilucoids group, all species show a strong correlation with salinity. The abundance of Gymnodinoids and Noctilucoids was lower than that of other morphospecies groups throughout the study period. Distinct temporal and spatial variations in dinoflagellate cell densities were clear. Cell density changes may associate with the salinity concentration. (Table 6).

Table 6. Correlation coefficients of Gymnodinoids and Noctilucoids and salinity.

No.	Gymnodinoids and Noctilucoids	2012	2013	2014
1.	*Gyrodinium estuariale*$^{++}$	0.74	0.72	0.93
2.	*Noctiluca scintillans*$^{++}$	0.88	0.64	0.61

(++) = strongly correlated, (±) = more or less correlated, (-) = less correlated

In the Prorocentroid morphospecies group, *P. rostratum* shows a strong correlation with salinity while *P. micans* shows less correlation with salinity. *P. gracile* and *P. lima* show more or less correlation with salinity. In the Dinophysoid group, *D. caudata* shows less correlation with salinity during the study period, 2012-2014. The other species in the group show a strong correlation with salinity.

In the Gonyaulacoid group, C. dens, C. furca, C. fusus, C. horridum, C. trichoceros, C. tripos, G. polygramma, G. spinifera, and Pyrophacus magnificus show strongly correlated with salinity during the study period. Alexandrium concavum, C. extensum, C. inflatum, C. porrectum, C. macroceros, C. schmidtii, Pyrocystis lunula, and Pyrophacus steinii show more or less correlated with salinity. C. breve, C. lineatum, and Spiraulax kofoidii show less correlation with salinity.

In the Peridinoid group, *Protoperidinium depressum, P. oblongum, P. oceanicum, P. pyreforme*, and *Podolampas palmipes* show a strong correlation with salinity during the study period. *Peridinium pentagonum,* and *P. elegans* show more or less correlation with salinity.

In Gymnodinoid and Noctilucoid group, *G. estuariale* and *N. sintillans* show a strong correlation with salinity during the study period.

4. Conclusions

In terms of dinoflagellates distribution which was based on different salinity regimes, the Gonyaulacoid species, *Ceratium* comprises 65% and stands first in the dinoflagellate community. In the Dinophysoid group, *Ornithocercus* takes 60% in species composition. Moreover, in the Peridinoid group, *Protoperidinium* takes 57% in species composition of it. In the study areas, 52.6% of dinoflagellates are strongly correlated with salinity while 13.2% shows less in correlation with salinity. Braaurd (1961) suggested that some dinoflagellate species such as *Ceratium* spp., *Peridinium* spp. and *Prorocentrum* spp. reproduced more actively at the lower salinities. Thus, changing salinity in nearshore areas might influence the dinoflagellate species composition.

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ARTICLE

Makran Coastal Zoning for the Construction of New Marine Areas based on Hydrological and Hydraulic Characteristics Using Satellite Data and Spatial Analysis

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Makran coasts
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ABSTRACT

On one hand, the diversity of activities and on the other hand, the conflicts between beneficiaries necessitate the efficient management and supervision of coastal areas. Accordingly, monitoring and evaluation of such areas can be considered as a critical factor in the national development and directorship of the sources. With regard to this fact, remote sourcing technologies with use of analytical operations of geographic information systems (GIS), will be remarkably advantageous. Iran's south-eastern Makran coasts are geopolitically and economically, of importance due to their strategic characteristics but have been neglected and their development and transit infrastructure are significantly beyond the international standards. Therefore, in this paper, with regard to the importance of developing Makran coasts, a Multi-Criterion Decision Analysis (MCDA) method was applied to identify and prioritize the intended criteria and parameters of zoning, in order to establish new maritime zones. The major scope of this study is to employ the satellite data, remote sensing methods, and regional statistics obtained from Jask synoptic station and investigate the region's status in terms of topography, rainfall rate and temperature changes to reach to a comprehensive monitoring and zoning of the coastal line and to provide a pervasive local data base via use of GIS and MCDA, which will be implemented to construct the coastal regions.

In this article, while explaining the steps of coastal monitoring, its main objectives are also explained and the necessary procedures for doing so are presented. Then, the general steps of marine climate identification and study of marine parameters are stated and the final achievements of the coastal monitoring process are determined. In the following, considering that this article focuses on the monitoring of Makran beaches, the method of work in the mentioned region will be described and its specific differences and complexities will be discussed in detail. Also, the impact of such projects on future research results will be discussed.

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1. Introduction

Makran beaches as one of the most important aquatic habitats in the country have been strategically neglected due to the lack of a comprehensive and integrated management approach in recent years. In order to manage the strategic area of Makran, the use of satellite data and spatial analysis provides us with valuable information for a comprehensive monitoring. However, the spatial information of many of the world's aquatic habitats is considered to be one of the main unknowns in the study of water resources. For reasons such as high costs and lack of necessary equipment, Makran beaches lack accurate information on spatial changes, which is one of the main limitations of this study.

The effects and natural phenomena of the earth's surface are changing rapidly, and these changes are remarkable throughout human life [1]. One important point is that these changes can be carefully reviewed so that natural and human factors recognize these changes; therefore, coastal areas, the lake interior, lake fluctuations and other important parameters are considered as ecological environments [2]. In this context, monitoring and evaluating such areas can be considered as an important issue in national development and water resource management. With the advancement of marine science and technology and stakeholder engagement, it is possible to solve the problems [3]. Marine and coastal studies provide decision makers with plenty of information to manage coastlines. Existing regional management plans for regional sustainable development in coastal areas do not provide the intended purpose for the construction of new offshore areas[5]. To ensure the sustainable development of offshore areas, the conservation of coastal resources is a requirement[6]. It is not clear to the departments and developers of the new maritime areas which areas can be used for offshore projects, MFZ method can be used to clarify many issues[7]. Thus, over the past few decades, the use of measuring technology to detect such changes over time has attracted the attention of various researchers [8].

Understanding natural potential, including the climate of each region as the basis for human activities, forms the basis of environmental planning. Earth warming research provides an important insight into the response to terrestrial ecosystems [9]. Lack of knowledge of the sub-regions of the regions, causes the economic and agricultural planning fail. For this reason, the importance and necessity of identifying homogeneous climatic regions has long been of concern to geographers and climatologists, and has led to the development of diverse climatological methods such as Sylaninov, Hansen, Coupon, De Martonne, Embereger, etc. Makran coast in the southeast of Iran is of geopolitical, geostrategic and geo-economic importance due to its strategic location and characteristics. The existence of a free trade-economic zone in Chabahar, the existence of suitable beaches, land and proper shelter along the coast, the existence of excellent platforms for transit and shipping, the presence of small bays (banks), the presence of coasts with adequate defense capabilities, the proximity to free waters and the proper operational depth Oman Sea, the presence of naval areas of the army, the existence of the necessary conditions for the expansion of military units and the adaptation of the military area by political divisions are part of the capabilities of the region, but over the past decades, due to more focus on Gulf ports and beaches, these capabilities have not been used. Makran's lanes are not only the most developed Iranian seaboard, but also on the basis of development indicators, this axis is among the most rebellious areas in Iran. However, the future development of the country, especially in the Middle East, depends to a large extent on the geographical and coastal situation of the Oman Sea. Considering the above, fertilizing the capabilities of these important beaches will increase Iran's geopolitical weight in the region and even in the world. Zoning is an appropriate tool for guiding the use of sustainable regions, and its growing effectiveness is undeniable among scholars [10]. Zoning is an approach that can provide a good prospect for researchers to explore different areas for human activities [11]. It shows the zoning of marine activities in different regional scales [12].

Marine spatial planning (MSP) is increasingly considered an effective tool that can resolve conflicts among various human uses as well as the conflicts between human uses and the marine environment. Many countries such as Australia, United Kingdom, Germany, Belgium, and United States have already initiated or implemented MSP. In China, marine functional zoning (MFZ) has developed independently since it was first proposed by the Chinese government in 1988 [14].

In marine protected areas (MPAs), zoning schemes can help balance multiple resource uses. Literature on ocean zoning design methods points out the need for analytical tools that guarantee stakeholder involvement and that address the unique spatial characteristics of the sea, especially under multiple jurisdictions [15].

To showcase the contribution of MFZ as a practical approach for Xiamen integrated coastal management (ICM) [16], the five dimensions of integration in ICM are applied as an analysis framework. Firstly, through compiling of the historical data and documents of the sea uses and marine environments, and socioeconomic status as well, the key drivers of initiating MFZ in the 1990s is summarized

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as increasing but incompatible and even conflicting sea uses, degrading marine environments due to negative effects of intensified human activities, and the lack of coordinating mechanism which has worsened the use-use and use-environment conflicts. Secondly, the technical guidelines and adaptive evolvement of Xiamen MFZ is introduced, and the achievements of Xiamen MFZ are explored. Based on the above analysis, the relationships of MFZ and ICM is looked into the dimensions of legislation, coordinating mechanism, scientific and technical support, integrated law enforcement and public participation; and how MFZ contributes to ICM in integration of dimensions of intergovernmental, inter-sectoral, land and sea, science and management, and multiple disciplinary is analyzed in-depth [16].

By collecting thin sections, the sediments of the area are studied and their types are determined. Finally, combining these two sources of information, potentially suitable and unsuitable areas for the construction and development of jetties, ports and fuelling jetties are determined. It was shown that factors such as fluctuations in the sea level, tectonic processes, climatic atmosphere, hydraulic processes, especially tidal currents, human interference, and construction activities in the jetties and these coastal regions are the most destructive and constructive forces at work in the coastal regions [17]. The morphology of six adjacent major catchments draining the onshore Makran accretionary wedge in southeast Iran and southwest Pakistan was studied to examine how the channel pattern and the length profiles may reflect the recent and active growth of the wedge. Qualitative field surveys were combined with the quantitative analysis of channel steepness and concavity measured from digital elevation models. These profiles were compared with modelled profiles using a stream power approach assuming homogeneously uplifting, uniform rock substratum. Results show a distinct difference between the studied western and eastern catchments [18].

The present study aims to classify the climatic and zoning of Makran coastlines, taking into account parameters such as coastline changes in order to achieve a comprehensive location database for the construction of maritime areas and optimal utilization of the functions of the region.

Table1. Monthly Raining Data from Jask Station

Geographical Location:					Jask Station				
Average Monthly Rainfall(mm)					Average Monthly Rainfall(mm)				
8	2016	2	2012	7.47	2008	3.33	2004	1.37	2000
10	2017	8.63	2013	7.56	2009	7.87	2005	6.04	2001
-	-	12.86	2014	5.11	2010	14.74	2006	2.73	2002
-	-	11	2015	2.62	2011	15.09	2007	1.43	2003

Table2. Monthly Temperature Data from Jask Station

Geographical Location:					Jask Station				
Average Monthly Temperature(oC)					Average Monthly Temperature(oC)				
27	2016	27.36	2012	26.87	2008	27.96	2004	27.76	2000
26.86	2017	26.85	2013	27.6	2009	27.36	2005	27.86	2001
-	-	26.89	2014	27.73	2010	27.3	2006	27.8	2002
-	-	26.1	2015	24.34	2011	27.46	2007	27.74	2003

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2. Methods and Material

The studied area in this research is the Makran coast in southwest of Iran. Makran is approximately consisted of Sistan and Balouchestan and part of south coast of Hormozgan in Iran.

2.1 Determination of the Studied Area's Climate

As it is pointed out, climate is one of the most effective phenomena of human life and recognition natural potentials i.e. regional climate is the basis of environmental planning. Hydraulic and hydrological characteristics are different in varied naval regions [13]. So in this study to determine the regional climate, required data of temperature and raining are prepared from Synoptic station in the port of Jask (Tables 1 & 2). Average data of raining and temperature are derived from using interpolation and then using climate determination methods De Martonne and Embereger, the climate of studied region is determined. In De Martonne method determination of climate type is based on yearly raining amount and temperature. In Embereger method which is more sensitive than De Martonne, besides using monthly raining amount, the coldest and hottest temperature of the month is used to determine the climate conditions.

2.2 Check the Topography and Tilt Status of the Area

A closer examination of the amount of precipitation and temperature and the subsequent mapping of the Makran coastal strips requires a knowledge of the topographic conditions of the area, because the precipitation varies with the variations in rainfall, and the type of climate in the study area can change. If the altitude changes are taken into account in the estimation of moisture and heat regimes, soil moisture and heat regimes in different regions will be very diverse. In order to investigate the topography status of the present study, we use the GIS techniques to estimate the required maps using the Raster and Wactar data. For this purpose, a 38-meter digital map taken from the ASTER satellite has been used. Also, for plotting consistent maps, necessary regression equations were determined using the mean annual rainfall and temperature data, and by making a series of calculations in the ArcGIS software, a digital elevation map prepared from the area in a 90-pixel, was used.

2.3 Area Zoning of Coastal Areas Using Climatic Data

In this study, climatic parameters of precipitation and temperature as the selected indicators for assessing the status of the region from the point of view of precipitation and temperature variations for the port of Jask station and 17 years of climate data from the synoptic station have been used. To do this, first, using SPSS software and Kolmogorov-Smirnov statistical test, the rainfall and temperature distribution data were analyzed. After examining the results, the least amount of data was extracted on each scale during the statistical period and its coverage maps in each scale during the statistical period, the Arc Map is drawn. Then, after the calculations, the results of the various interpolation methods of IDW and Kriging with a weighing power of one to five were evaluated. Also, for a better and more accurate assessment of coastline changes, using the MODIS satellite data from 2006 to 2016, the coastline of Makran has been reviewed.

3. Results and Discussion

3.1 Determining the Type of Climate in the Study Area

In order to calculate the Embereger relationship, the three following parameters are needed: average temperature of the coldest and warmest month of the year, and the mean precipitation (in millimeters). Despite the mentioned parameters, the relationship was calculated and based on Table 3, the climate of the study area was determined. According to the calculations performed to determine the climatic condition of the Embereger method, it was found that the port of Jask and the coastline are dry to semi-arid zones. Of course, the beach strips are more volatile than the area, and there is no barrier to building offshore areas. Secondary method, which is a more convenient way to determine the type of climate in most regions of the country, uses the annual average of rainfall and temperature in the area for this purpose. Using the calculations done by the method of the De Martonne, the area has a dry to semi-arid state. The corresponding coastal strip has high evaporation due to extreme temperature fluctuations and precipitation and proximity to the equator. Table 4 shows the results of calculations of the De Martonne method based on Jask's synoptic station.

Table 3. Embereger Formula Calculation and Regional Climate Determination

Results	Climate Type
Q<28	Dry
8>m>5.1	Hot

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Table 4. De Martonne Formula Calculation and Regional Climate Determination

Results	Climate Type
I<10	Dry

3.2 Review the Process of Precipitation and Temperature Changes

In order to better match and to better characterize the result obtained from the relations between Embereger and De Martonne, the diagram of precipitation and temperature variations in the region and the coastal strip is drawn up (Figures 1 and 2). According to the precipitation fluctuation chart, in this coastal strip the range of precipitation variation between 5 and 12 mm is very common. On the other hand, by examining the temperature changes, the 17-year average for this port was 26 degrees. This amount of temperature is very important during the year from the examination of rainfall conditions and situation in the area. As this temperature shows that in the area and coastline the evaporation phenomenon is common in most of the year, and this evaporation is unavailable due to the lack of a coherent source such as a mountain that can enter the region's hydrological cycle again with cooling. This low rainfall it can also be concluded from the sea currents and the climatic conditions that cause rainfall in the coastal regions; therefore, it can be concluded from Embereger and De Martonne 's relations that the climate of the region is dry. It should also be noted that during the period from 2000 to 2007, temperatures were high, but this temperature dropped by 2 degrees in 2017. Of course, these climatic conditions can have an impact on coastal factors, so that many projects in the coastal areas do not have much progress.

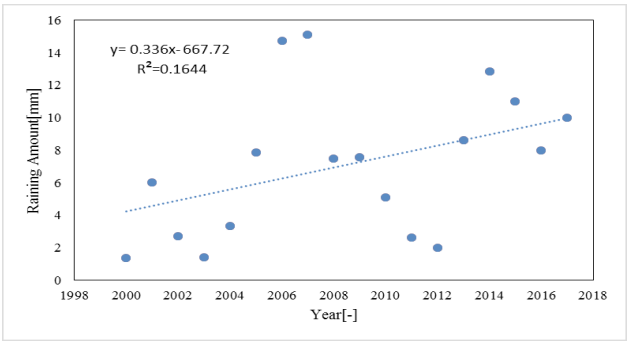

Figure 1. Raining Changes in Jask plot

3.3 Check the Topography and Tilt of the Area

Considering the conditions studied in the temperature variation and precipitation of the coastal strip, it is necessary that the area be considered in terms of topographical features and other effective factors considering the strategic nature of the Jask area, especially the Makran coast. In Figure 3, the map of the area and the coastal strip is specified. According to the map, you can see the role of temperature and precipitation in the region. Coastal areas are up to kilometers without mountains and highlands, which can be attributed to precipitation shortages in the region and high temperatures. However, according to the map, the existence of plains and coastal areas with a slope of less than 9 percent, as well as the existence of gorgeous rivers and natural attractions in the region provide a great opportunity to build tourist and recreational areas along the Makran coastline.

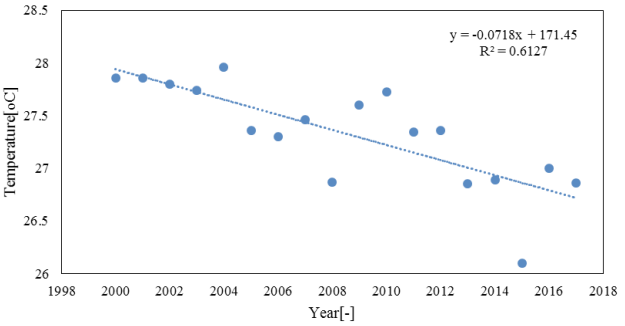

Figure 2. Temperature Changes in Jask Plot

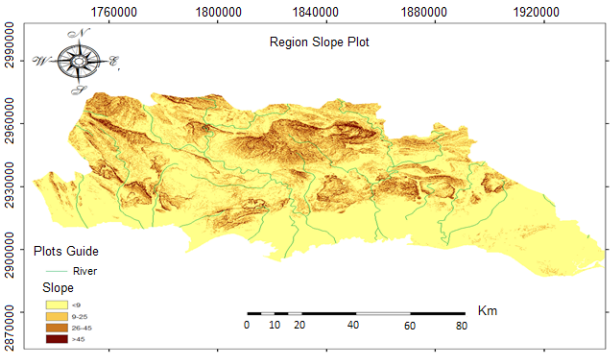

Figure 3. Regional Topology and Slope Plot

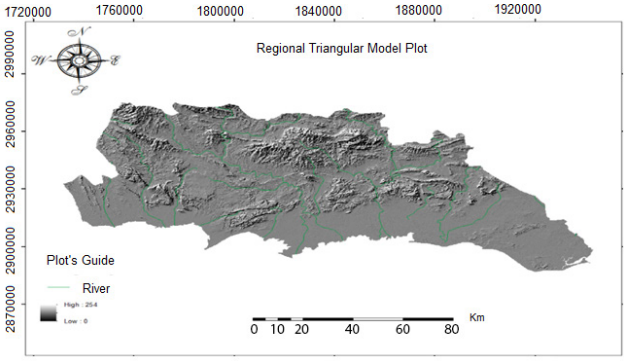

Figure 4. 3D View from Region

 DOI: https://doi.org/10.36956/sms.v2i2.329

Further, Arc Hydro software has been used to more accurately assess the status of the area, the existing rivers, and follow up of surface water behaviors on the route. Figure 4 shows the image obtained from this software.

Using the GIS software and measurement tool, it is also possible to predict the status of the region and the coastline using hydrological and climatic data. For this purpose, Arc Hydro, one of the options available in the ArcGIS software, has been used based on the digital map of the area, the status of the Arctic and the rivers. This software, which has been shown in Figure 5, has a high ability to determine and assess the physiological characteristics of the region. In this picture, the coastal strip has the proper features for implementing many economic projects in the region.

For more accurate evaluation of temperature and precipitation fluctuations in the area and coastal strip, consistent maps and homogeneous maps were provided with topographic maps, data obtained from the Jask port's synoptic station, and made by a series of calculations in ArcGIS software (Figures 6 and 7).

According to the regional map of the area, there is a higher rainfall in the central parts of the port of Jask and there is no shortage of factors in the coastal areas to avoid evaporation, but the amount of precipitation is lower than other areas. In the entire coastal zone of Makran, this issue is clearly visible. According to the coherent map, the coastal strip has a higher temperature than the central and upland areas of the port of Jask. This state of affairs treats the situation in the region to a large extent, as the high temperature conditions associated with humidity disrupt many activities in the region.

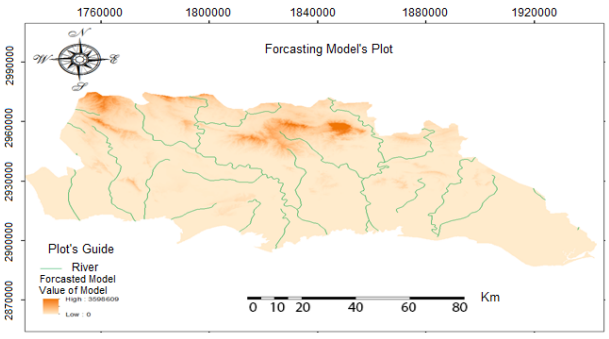

Figure 5. Forecasted Model using Hydrological and Climatic Derived from ArcGIS

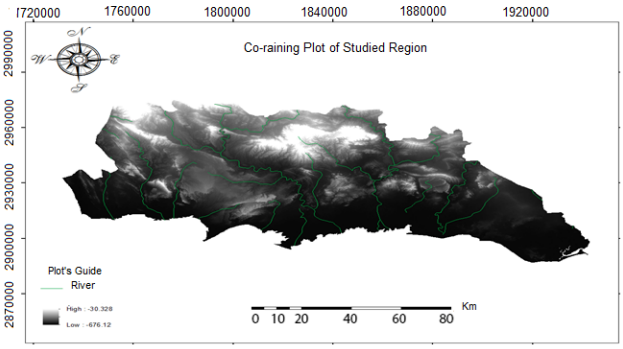

Figure 6. Co-raining Plot of Jask

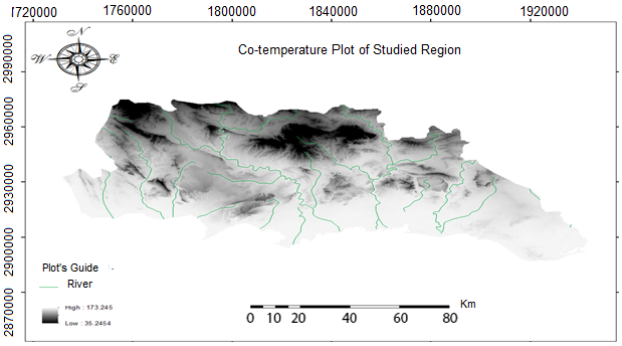

Figure 7. Co-temperature Plot of Jask

4.3 Coastal Zoning Using Climatic Data

In this study, climatic parameters of rainfall and temperature have been used as indicators for determining the status of the region. To do this, we first used the Kolmogorov-Smirnov test to investigate the rainfall distribution data and temperature of the area, and the results are presented in Tables 5 to 7. Considering the significant level (P) of more than 0.05 (for rainfall data equal to 0.13 and for temperature data equal to 0.093), data from rainfall and temperature have a good level of coastline level; Therefore, rainfall and temperature data are normal and a parametric test can be applied to these data. After reviewing the output results, the least amount of data was extracted on each scale during the statistical period and its coverage maps were plotted in Arc Map for each scale during the statistical period. After calculating, the results of various interpolation methods for IDW and Kriging with a weighing power of one to five were evaluated. Among interpolation methods, the two-dimensional weighted photo-IDW method with the least power for rainfall parameters and temperature the error value of the RMSE and MAPE and MBE errors are much more than other zoning methods. The lowest RMSE estimate for each of the indices with respect to the potentials is 0.22 and 0.4 respectively. Hence, this method is the most appropriate method for zoning the status of water resources in the Makran region and the

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coastal strip. The rainfall and temperature zone maps were also prepared in the coastal zone by precipitation and temperature data (Figures 8 to 11). Investigation of the maps shows that the coastline has the least rainfall distribution and the highest dispersion in the highlands of the port of Jask but according to the temperature zoning map, in the coastal areas, the highest amount of dispersion and the lowest temperature in the highlands. Coastal areas, such as high temperatures and high evapotranspiration, are in a state of inferiority, so that many projects are not in this situation.

Table 5. Result of Kolmogorov-Smirnov Test for Raining Data using Software SPSS One-Sample Kolmogorov-Smirnov Test

		V1
N		17
Normal Parameters[a,b]	Mean	7.42145061728395E0
	Std. Deviation	4.186981284660888E0
Most Extreme Differences	Absolute	0.113
	Positive	0.113
	Negative	-0.081
Kolmogorov-Smirnov Z		0.481
Asymp. Sig. (2-tailed)		0.975

a. Test distribution is Normal.
b. Calculated from data.

Table 6. Result of Kolmogorov-Smirnov Test for Temperature Data using Software SPSS One-Sample Kolmogorov-Smirnov Test

		V1
N		17
Normal Parameters[a,b]	Mean	2.72981372549020E1
	Std. Deviation	0.485733938643530
Most Extreme Differences	Absolute	0.149
	Positive	0.093
	Negative	-0.149
Kolmogorov-Smirnov Z		0.613
Asymp. Sig. (2-tailed)		0.847

a. Test distribution is Normal.
b. Calculated from data.

Table 7. Kolmogorov-Smirnov Test Table for Raining and Temperature

Kolmogorov-Smirnov		Parameter
Siq	N	
0.975	17	Raining
0.847	17	Temp

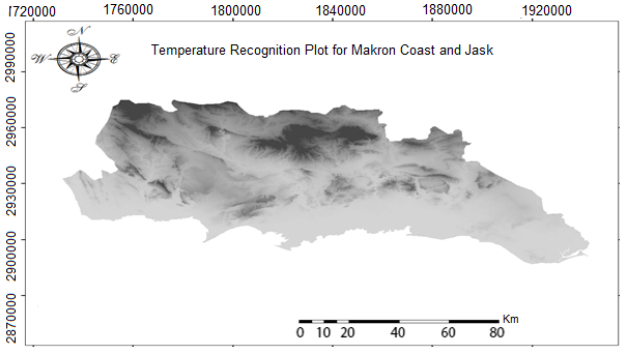

Figure 8. Regional Temperature Plot for Jask and Makron Coast using IDW Method

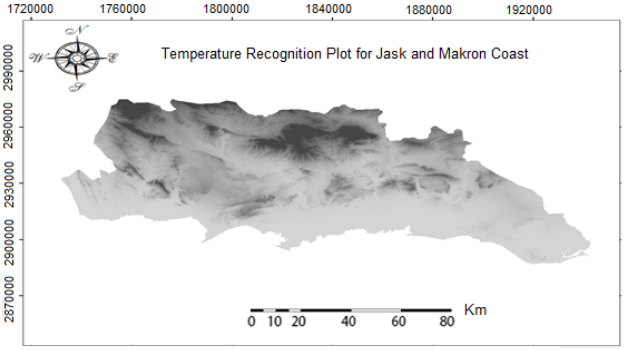

Figure 9. Regional Temperature Plot for Jask and Makron Coast using Kriging Method

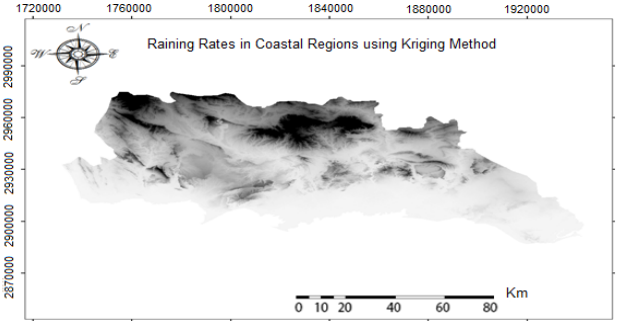

Figure 10. Regional Raining Plot for Jask and Makron Coast using IDW Method

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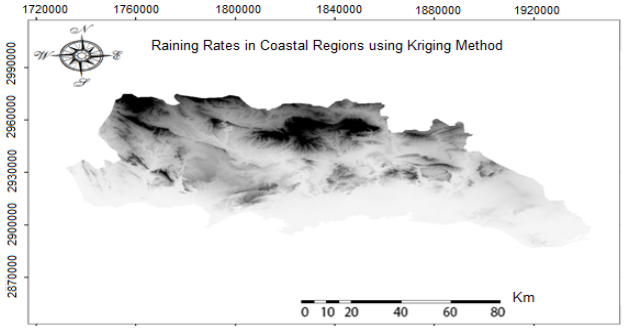

Figure 11. Regional Raining Plot for Jask and Makron Coast using Kriging Method

3.5 Changes in Lines of the Makran Coast

In this study, the changes in the Makran coastline were reviewed using MODIS satellite data between 2006 and 2016. In Figure 12, the accuracy of the measured data can be seen in the extent and evolution of the Oman Sea in the coastal strip of Makran. In Figure 13, coastline changes were monitored for three consecutive years between 2014 and 2016. Assessing the amount of seafront progress or resettlement can certainly be important in making decisions for the construction of residential and commercial areas.

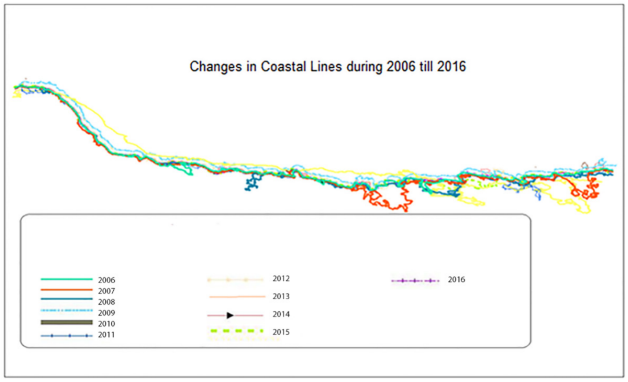

Figure 12. Changes in Coastal Lines during 2006 till 2017

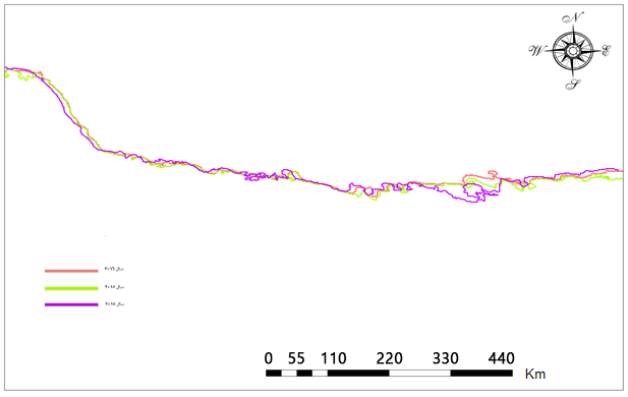

Figure 13. Changes in Makran Coast during 2014 till 2016

4. Conclusions

The climate of the studied area was determined by Embereger and De Martonne methods and 17 years of climatic data obtained from the synoptic station of port of Jask. According to the calculations carried out with the parameters of the warmest and coldest months of the year, it was found that the port of Jask is arid to semi-arid. The process of rainfall and temperature changes also indicates that in most days of the year, the phenomenon of evaporation is common in the region and coastal strip, and this evaporation is due to the lack of a coherent source such as mountains and suitable flows to create an outdated hydrological cycle and this low rainfall can also be deduced from sea currents and climatic conditions that cause rainfall in coastal areas. Of course, the beach strips are more volatile than the area, and it should not be difficult to construct sea areas according to the conditions. Considering the geographical conditions, scoring and determining the relevant criteria, the central part to the east of the Makran coast has a high value from the point of view of the creation of maritime conditions. This area is also suitable for hydraulic topography. In order to more accurately assess the precipitation and temperature conditions, the region was also examined for topographic properties. The obtained maps indicate that the coastal areas have the lowest tilt and topography that is very flat and smooth, up to kilometers without mountains and highlands, but, according to the map, the existence of plain and coastal areas with a slope of less than nine percent As well as the presence of rainy rivers and natural attractions in the region, it has provided very good conditions for the construction of new sea areas along the Makren coastline. With the possession of topographic maps and data on temperature and precipitation, we developed consistency maps. According to the regional map of the area, there is a higher rainfall in the central parts of the port of Jask and there is no limiting factor in coastal areas as a way of preventing the evaporation from wasting. The amount of precipitation is lower than other areas. According to the coherent map, the coastal strip has a higher temperature than the central and upland areas of the port of Jask. This state of affairs treats the situation in the region to a large extent, as the high temperature conditions associated with humidity disrupt many activities in the region. According to the topographical and hydrological conditions of the Makran coast, the zoning of the coastal areas is favorable and suitable so the geographical and natural parameters are effective in determining the status of the coast and zoning. In this study, regional distribution of coastal areas was performed using SPSS software and Kolmogorov-Smirnov test to analyze

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rainfall and temperature data of the region. The results showed that the data from rainfall and temperature have a good significance at the coastal level, so the rainfall and temperature data are normal and the parametric test can be applied to these data. After calculating the results of various interpolation methods for IDW and Kriging with a weighing power of one to five, it was found that the weight difference method (IDW) with a power of two for rainfall and temperature parameters had the lowest RMSE error and MAPE and MBE errors compared to other methods are zoning. Rainfall and temperature zone maps were also prepared in the coastal zone by rainfall and temperature data. Investigation of the maps shows that the coastline has the least rainfall distribution and the highest dispersion in the highlands of the port of Jask but according to the temperature zoning map, in the coastal areas, the highest amount of dispersion and the lowest temperature in the highlands. Coastal areas, such as high temperatures and high evapotranspiration, are in a state of inferiority, so that many projects are not in this situation.

Valuing and determining the appropriate points for the expansion of the marine areas, according to the views of the relevant experts in the field of marine science, can be an appropriate option. Multi-criteria methods can also provide good and precise results by prioritizing and weighting different parameters. Ultimately, the development of the Makran coast, despite some restrictions, is a national, regional and even international imperative. Development of basic facilities and expansion of commercial and recreational infrastructure can lead to national development in addition to improving the situation in the south-east region of Iran. Therefore, identifying and studying factors affecting the region's situation can be important in many aspects.

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ARTICLE

New Method for Building Vector of Diagnostic Signs to Classify Technical States of Marine Diesel Engine by Torsional Vibrations on Shaft-Line

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ABSTRACT

Vector of diagnostic signs (VDS) using torsional vibration (TV) signal on the main propulsion plant (MPP) is the vector of z maxima (or minima) values of the TV signal in accordance with the cylinder firing orders. The technical states of the marine diesel engine (MDE) include R= z+1 classes and are presented in z-dimensional space coordinate of VDS. The presentation of Dk, k=1÷R using z diagnostic signs (Vi, i=1÷z) is nonfigurative and quite complicated. This paper aims to develop a new method for converting VDS from z-dimensional to 2-dimensional space (two-axes) based on the firing orders of the diesel cylinders, as an equivalent geometrical sign of the all diagnostic signs. The proposed model is useful for presenting a technical state Dk in two-dimensional space (x, y) for better visualization. The paper verifies the simulation of the classification illustration of the 7–state classes for the MDE 6S46-MCC, installed on the motor vessel (MV) 34000DWT, using the new above mentioned method. The seven technical state classes (for 6-cylinder MDE, z=6) are drawn separately and visually in the Descartes. The received results are valuable to improve smart diagnostic system for analyzing normal/misfire states of cylinders in operation regimes.

1. Introduction

The TV signal (TVS) contains much important information about the misfiring / normal working conditions of every cylinder in the multi-cylinder marine diesel engine (MDE) [1]. The characteristics of the TVS identifying in time or frequency domains are used to estimate the technical states of the diagnostic object (DO) and called diagnostic signs.

In the works [1, 2, 4], the VDS are formed from the maxima (VA) or minima (VB) of the TVS correspondence with firing order of each cylinder. The size of the VDS is equal to the number of cylinders in the DO. The z-dimensional VDS are used for classifying the technical states (normal / misfiring conditions) of every DME cylinder, in this case DO is 6 cylinder MDE type 6S46 MCC-7 of MAN-BW

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manufactory.

It's hardly to illustrate every technical state D_k, k=1÷R in z-dimensional space V= [V_1…V_z] of the VDS (V=VA or V=VB; VA= [VA_1... VA_z] or VB= [VB_1... VB_z]) because imagining mathematic models in the multi-dimensional space is quite complicated. In many cases, the illustration of D_k (V_1, V_2 … V_z) is divided in to a number of a pair of two-dimensional space (V_i, V_j); i ≠j, i=1÷z; j=1÷z [4].

To overcome the above-mentioned presentation inconvenience, the authors convert VDS from z-dimensional to 2-dimensional space. From there, the diagnosis and identification processes could be solved in a more visualization way and easily applied in real-world diagnostic problems.

2. Research Method

2.1 Modeling New Two –dimensional VDS from VA or VB

Let us assume that the TV signals are simulated (or measured) in a working cycle of MDE containing z cylinders. The signal normally has a number of samples, N=1024 or 2048. The signal is divided in to z parts, and every part has N_c = [N/z] samples. In the part in accordance with firing order of every cylinder, we find the maximal and minimal values. We conduct the VA and VB vector of the diagnostic signs from these values.

The firing order of every cylinder is given in the MDE technical documents, such as the 6S 46MCC shows the order [6]: 1-5-3-4-2-6. The parameter features (VAm, VBm) of m^{th} –cylinder are de-phased α_m (degree) in accordance with the first cylinder (two-stroke diesel engine): α_1=0; α_5= 60°; α_3= 120°; α_4= 180°; α_2= 240°; α_6= 300° or in radian: α_1=0; α_5= π/3; α_3= 2π/3; α_4= π; α_2= 4π/3; α_6= 5π/3.

In generally, we conduct the de-phase vector of the working cylinders α:

$$\boldsymbol{\alpha} = [0, \alpha_2 \ldots \alpha_z], \text{ (radian)} \quad (1)$$

The new diagnostic vectors VN are calculated as follow:

$$\mathbf{VN}_x = \sum_{i=1}^{z} \mathbf{V(i)cos(\alpha(i))}; \mathbf{VN}_y = \sum_{i=1}^{z} \mathbf{V(i)sin(\alpha(i))} \quad (2)$$

Where, V= [V (1), V (2) … V (z)], and V=VA or V=VB.

Every class D_k is written by two reference parameters: the mean vector μ_k and the covariance matrix K_k in accordance with the two-dimensional VDS VN= (VN_x, VN_y), k=1÷R.

Illustration of the cylinder working conditions in the Descartes (VN_x,VN_y).

The z –cylinder MDE is classified into R =(z+1) technical classes D_k as above mentioned for diagnostics of the normal or misfiring state of cylinder in accordance with the Rules for Classification and Construction of Sea-going Ships [7].

The block scheme for building the new VDS VN (VN_x, VN_y) and illustrating the R states via the 2-dimensional space is shown in Figure 1.

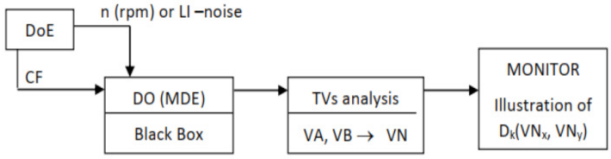

Figure 1. Block scheme for building new VDS in two-dimensional space VN(x, y)

DoE –Design of Experiments, CF –Vector of the z firing coefficients, MDE as a DO; VA, VB –vector of diagnostic signs (z elements of maxima or minima);VN –new vector of two equivalent elements in two-dimensional space (x,y)

In measuring process, we supposed that the revolution n (rpm) and the Load Index (LI) are fixed. However, the real measured signal has some random components and measuring errors. Therefore, we conducted the measuring process ten repeated times with random noises, and the measurement device error is ±5%. This ±5% is bigger than almost thresholds of precise measuring devices in the market today [4].

The main controlling parameters of the technical states of all cylinders are firing coefficients, which are written in the form of vector CF = [Cf (1)… Cf (z)]. The real firing processes are random and for diagnostics model, we assume that firing coefficient Cf (k) is varied with ±5% in accordance with the mean value. In the case of normal working, the Cf = [0.9, 1.0], and with the misfiring state, Cf = [0.0, 0.1]. For every cylinder there are three levels of one firing regime to be examined.

The design of experiments has N_n revolution regimes, for example n_{mean} = 75 rpm, the ΔN=5%.75 =3.75. We would carry out the numerical experiments at N_d = {71÷79} (rpm), for example at the n_{mean} = 75 rpm, N_d = 9 experiments.

The design of experiments has R= (z+1) technical state classes. Thus, we conduct $N_s = 3^z$ experiments for every revolution regime. For example, z=6, N_s = 729.

The total number of experiments of the DoE is $N=N_d*Ns$. Let us assume z =6, and we conduct each revolution 10 times (in accordance with the real measuring repeat times, N_d =10), the total N is 10* 729 =7290 (experiments).

After building database from the measured (simulated) TVS, the authors analyze TVS to find the VA or VB, and

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finally to draw the new VN-database for the R= (z+1) = 7 states. The VN–database is drawn visually in the two-dimensional (VN_x, VN_y) axes, in accordance with Equation (2).

To diagnose the misfire of any cylinder in the multi-cylinder MDE by classification methodology we have to make the new standard diagnostic characteristics and new diagnostic classifier using the new vector of diagnostic signs VN(x, y).

2.2 Modeling Standard Characteristics of MDE on the New VDS VN(x,y)

The technical states of MDE are grouped in to R=z+1 classes, written with the symbol D_k, k=1…R. Every class has the called referenced (standard) characteristic to identify one with other [1]:

$$\mathbf{D_k}:\ \mathbf{D_k}(\boldsymbol{\mu}_k,\mathbf{K_k});\ \boldsymbol{\mu}_k=[\mu_{kx},\mu_{ky}];\ \mu_{kx/y}=\frac{1}{m}\sum_{i=1}^{m}VN_{x/y}(i)$$

$$\textit{Coded in LabView}:\ \mathbf{K_k}=\mathrm{cov}(\mathbf{VN});\ \boldsymbol{\mu}_{kx/y}=mean(\mathbf{VN}_{x/y}) \quad (3)$$

The covariance matrix K_k is calculated.

$$\mathbf{K_k}=\frac{1}{m}\tilde{\mathbf{V}}_k.\tilde{\mathbf{V}}_k^T;\tilde{\mathbf{V}}_k=\mathbf{VN_k}-\boldsymbol{\mu}_k \quad (4)$$

2.3 Diagnostics Classification of MDE on the New VDS VN(x,y)

The current considered state D_c is presented in the similar form with Equation (3) in the following [1, 4]:

$$\mathbf{D_c}:\ \mathbf{D_c}(\boldsymbol{\mu}_c,\mathbf{K_c});\ \boldsymbol{\mu}_c=[\mu_{cx},\mu_{ky}];\ \mu_{cx/y}=\frac{1}{m}\sum_{i=1}^{m}VN_{x/y}(i) \quad (5)$$

The solution of the diagnosis is finding minimum of Mahalanobis distance d_{ck} from distance set:

$$\mathbf{d_{c=m}}=\min\{\mathbf{d_{ck}},k=1,2\ldots\mathbf{R}\}\Rightarrow\mathbf{D_c}\equiv\mathbf{D_m} \quad (6)$$

The Mahalanobis distance between two classes "c" and "k" is defined below.

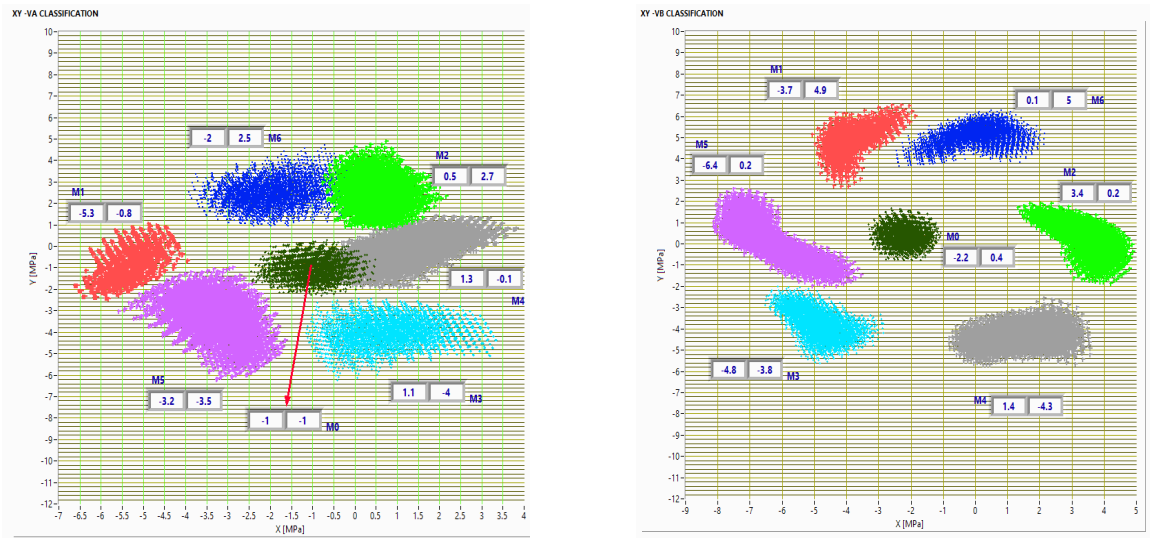
$$\mathbf{d_{ck}}=(\boldsymbol{\mu}_k-\boldsymbol{\mu}_c)\mathbf{K_{ck}^{-1}}(\boldsymbol{\mu}_k-\boldsymbol{\mu}_c)^T;\quad \mathbf{K_{ck}}=0.5(\mathbf{K_c}+\mathbf{K_k}) \quad (7)$$

Where, K_{ck} – compound covariance matrix of the two matrixes K_c and K_k.

3. Cases Study: Building the Two-dimensional VDS for Diagnosing the 6S46 MCC

The MDE type 6S46 MCC is installed on the general cargo motor vessel with 34000 DWT (MV 34000 DWT). The TVS of the ship MPP are conducted and supposed to DNV (register) approve by HuDong manufactory [6]. The method and software for automatic torsional vibration calculation (SATVC) are developed at Vietnam Maritime University [0, 5] for this MPP on LabView platform. The SATVC has the features to automatically calculate one of the 7 normal/ misfiring states of the 6 cylinders with revolution regimes N= [0.4, 1.2] NMCR, where N_{MCR} -maximal continuous rate (rpm) and in this case of MV 34000 DWT, N_{MCR} =129 rpm.

For diagnosing technical states normal / misfiring, the diagnostic revolution regimes have to be far from reso-



(a) (b)

Figure. 2 Illustrating the seven classes of the MDE 6S46MCC on MV 34000 DWT via new two-dimensional space (VN_x, VN_y) in accordance with VDS VA (a) and VB (b)

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nance revolution ranges of the torsional vibrations of the MPP because in the resonance or near–resonance revolutions the TVS are quite excited and too large. Therefore we have to calculate the freedom TV for the MPP.

Table 1. Freedom resonances of the MPP on the MV 34000 DWT

n01 (rpm)	**337.16**							
Harmonic	k	7	6	5	4	3	2	
nE(rpm)		48.2	56.2	67.4	84.3	112.4	168.6	
n02 (rpm)	**1436.02**							
Harmonic	k	15	14	13	12	11	10	9
nE(rpm)		95.7	102.6	110.5	119.7	130.5	143.6	159.6

The resonances of the first and second modes of the MPP on the MV 34000 DWT are also defined by the SATVC, especially by the freedom torsional vibration module. The results of the freedom TVs are shown below[3,4]: n_{01}=337.16 rpm; n_{02}= 1436.02 rpm. The revolutions of the DME on the MV 34000 DWT at the interval [52, 155] rpm are resonances that are shown in Table 1.

The interval N_d = [71, 80] is selected for diagnostic revolution regimes.

The two-dimensional illustrations of the seven technical normal or misfiring conditions in cylinders of the DO are shown in Figure 2 using the simulation software which is developed in LabView by authors.

Figure 2(a) shows that when using the maxima VA of the TVS, the pairs of state classes: (D_0 and D_4), (D_2 and D_4), and (D_6 and D_2) couldn't be separated fully in new two-dimensional VN_A (VN_{Ax}, VN_{Ay}). However, Figure 2(b) shows that using the minima VB of the TVS, the pairs of state classes are very well separated in the new two-dimensional VN_B (VN_{Bx}, VN_{By})

4. Conclusions

Using the new method for building two-dimensional VDS has the advantages in classifying R technical states of MDE. The authors applied the new approach for diagnosing the technical sates in the two -axes Descartes (VN_x and VN_y) using the maxima and minima VDS of the shaft-line TVS. The results show that the minima VDS produces the better classification performance than the maxima VDS.

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Abbreviation list

CF	Vector of firing coefficients
DO	Diagnostic object
DoE	Design of Experiments
DWT	Dead weigh tonnage
MDE	Marine diesel engine
MPP	Main propulsion plant
MV	Motor vessel
SATVC	Software for automatic torsional vibration calculation
TV	Torsional vibration
TVS	Torsional vibration signal
VDS	Vector of diagnostic signs
VN	New vector of two equivalent elements

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