MODERN OCEANOGRAPHY – FROM CLIMATE CHALLENGES TO STRATEGIC AND PUBLIC HEALTH IMPLICATIONS –

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The Black Sea is considered one of the most affected areas in Europe, with a pollution level of almost 98%, which is a major public health alert. This study examines the profound transformations of modern oceanography, highlighting how marine environmental degradation reconfigures global security and public health. The research examines the weaknesses of the Romanian Black Sea sector and the way they affect navy activities under the circumstances of climate change and intense anthropological pollution.

Pollution is not only an ecological problem, but also an operational obstacle. The presence of contaminated macro-waste and sediments in Romanian ports and coastal areas increases the risk of damage to propulsion systems and may distort acoustic (sonar) sensor signals essential for national security missions in the western Black Sea basin.

Through comparative analysis methods, the results of the study underline the need to implement advanced filtration systems on board ships to ensure the resilience of Romanian naval forces in an increasingly degraded marine environment.

Keywords: oceanography; marine pollution; naval actions; microplastics; public policies;

INTRODUCTION

Modern oceanography faces unprecedented pressures, ranging from climate change and massive pollution to the intensive exploitation of marine resources. These challenges generate a ripple effect, disrupting the balance of fragile ecosystems, global geopolitical security, and, by extension, public health, through the degradation of vital resources. Oceanography is the science that studies the oceans and their ecosystems, having a crucial impact on the global environment and natural resources. The strategic implications of oceanography are significant, influencing national security, maritime trade, and the management of marine resources. In the context of climate change, understanding the oceans becomes essential for developing sustainable and effective policies.

Contemporary oceanography analyses the impact of these challenges on public health and maritime security, paying particular attention to the effects of microplastics on the human body.

Although oceanography, as an integrative science, has made remarkable progress in recent decades, its field of study has nevertheless faced a series of persistent and interconnected challenges, such as: insufficient exploration of the ocean depths, the impact of climate change on marine ecosystems, and the alarming increase in microplastic pollution (Boșneagu, 2019). Contemporary oceanography analyses the impact of these challenges on public health and maritime security, paying particular attention to the effects of microplastics on the human body. In this regard, the present study evaluates public policies in the European Union and Romania in this field, rounding out the picture with an analysis of how marine pollution affects the success of naval surface and submarine operations.

TYPES AND SOURCES OF MARINE POLLUTION: FROM MICROPLASTICS TO CHEMICAL CONTAMINANTS

Despite significant advances in oceanographic research and technology, the field continues to face major challenges that limit our full understanding and sustainable management of the oceans. These challenges primarily concern ocean exploration, climate change, and marine pollution, each presenting complex scientific, logistical, geopolitical, and military issues.

The global ocean, which covers over 70% of the Earth's surface, plays an essential role in regulating the climate, conserving biodiversity and sustaining human life. However, its vast depths remain largely unexplored and poorly understood. Currently, less than 25% of the global ocean floor has been mapped at high resolution (Wölfl et al., 2019; NOAA, 2021). The global ocean absorbs approximately 90% of the excess heat generated by the greenhouse effect and 25-30% of anthropogenic carbon dioxide (IPCC, 2023). However, this particularly important protective function comes at a cost. Increased heat absorption leads to the warming of ocean waters; a fact that affects stratification, current systems, and the distribution of marine species (Pörtner et al., 2022). Simultaneously, CO_2 absorption causes ocean acidification, a chemical process that reduces the availability of carbonate ions needed by calcifying organisms, such as corals and molluscs (Doney et al., 2009).

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Another phenomenon, which is currently very pronounced, is ocean deoxygenation, the decrease in oxygen levels in the marine environment due to increased stratification and reduced upwelling. This process, exacerbated by warming, can lead to the expansion of hypoxic zones, also known as *"dead zones"*, where marine life cannot be sustained (Breitburg et al., 2018). Together, these processes threaten the integrity of marine ecosystems and their products, such as fish, as well as the maintenance of biodiversity, because of carbon sequestration and retainment.

Marine pollution remains an ever-present and worsening threat to the health of the oceans. Among the most visible and pressing forms of pollutants are plastics and microplastics, which are present in nearly all marine habitats, from the water's surface to the deepest ocean canyons (Jambeck et al., 2015). These pollutants cause physical, physiological, and health damage to marine organisms and also act as vectors for chemical contaminants and invasive species (Rochman et al., 2016). Microplastics, defined as plastic fragments smaller than five millimetres, originate from the degradation of large plastic waste or are produced directly in the form of granules or fibres used in cosmetics, textiles, and industrial processes. They have been detected in all areas of the ocean, from the surface to the abyssal sediments, and in marine organisms at all trophic levels (Andrady, 2011). The presence of microplastics in the marine food chain raises serious concerns regarding the transfer of these particles and associated toxic substances (e.g., phthalates, polychlorinated biphenyls/PCBs, heavy metals) to the final consumer: humans (Galloway et al., 2017). Numerous studies have demonstrated the accumulation of microplastics in the tissues of certain species of fish, crustaceans, and marine molluscs that constitute the human diet. In particular, bivalve molluscs, such as mussels and oysters, are considered relevant bioindicators of microplastic pollution, as they are consumed whole, including the digestive tract where these particles accumulate (Li et al., 2015).

In addition to plastics, chemical pollutants such as heavy metals, persistent organic pollutants, and pharmaceutical residues accumulate in marine food chains, with potential toxic effects on marine organisms and human consumers.

According to a study conducted in Europe, frequent consumers of seafood may ingest up to 11,000 microplastic particles annually (Van Cauwenberghe, Janssen, 2014). Although the size of the particles often prevents them from being absorbed into the systemic circulation, the smallest ones (<1 µm) can enter the bloodstream, lymph, or even tissues. The toxicological impact of microplastics on humans is still being investigated, but there is preliminary evidence of inflammation, endocrine disruption, and oxidative stress. Microplastics can act as carriers for toxic substances (e.g., bisphenol A, organochlorine pesticides), which can disrupt endocrine functions and affect fertility, neurological development, or increase cancer risk (Wright, Kelly, 2017). A relatively recent study (Vethaak, Legler, 2021) identified plastic fragments in human blood, confirming the possibility of systemic transport. Additionally, researchers have discovered microplastics in human placentas, raising concerns regarding prenatal exposure and the potential impact on foetal development (Ragusa et al., 2021). In addition to plastics, chemical pollutants such as heavy metals, persistent organic pollutants (POPs), and pharmaceutical residues accumulate in marine food chains, with potential toxic effects on marine organisms and human consumers. Furthermore, runoff from agriculture and nutrient-rich urban areas promote eutrophication, leading to harmful algal blooms and oxygen depletion.

Public exposure to microplastics is not limited to the consumption of seafood. It also includes drinking water, sea salt, the air we breathe, and plastic packaging. Thus, addressing this emerging risk requires an integrated *"One Health"* approach, which links environmental, animal, and human health. It is recommended to strengthen regulations regarding the use of single-use plastics, develop efficient wastewater filtration technologies, and support research on the toxic effects of microplastics on human health.

Bathymetric mapping is essential not only for understanding tectonic processes and the morphology of the ocean floor, but also for identifying biodiversity-rich habitats, such as hydrothermal and cold seeps (Jakobsson et al., 2020).

Technological and financial barriers continue to limit exploration of the deep ocean. Manned submersibles, autonomous underwater vehicles, and remotely operated vehicles have significantly improved the ability to investigate abyssal zones, but their operation and maintenance are costly (Levin et al., 2019). Thus, although the potential for scientific discoveries in the oceans is vast, including the identification of unknown species, ecosystems, and resources, human capacity to explore the hydrosphere remains limited (Boșneagu, 2022).

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PUBLIC POLICIES IN THE EUROPEAN UNION ON COMBATING MICROPLASTIC POLLUTION

The European Union has adopted an integrated approach to combating microplastic pollution, as part of the EU Strategy on Plastics in a Circular Economy (European Commission, 2018). The strategy includes specific measures, such as: banning single-use plastics (Directive (EU) 2019/904); regulating the content of intentionally added microplastics in cosmetics, detergents, and paints (European Chemicals Agency-ECHA, 2023); promoting technologies for capturing microplastics in waste water treatment plants; and investing in research through the Horizon 2020 and Horizon Europe programs to better understand microplastics and their effects on health and the environment. In addition, the EU has set recycling and energy recovery targets for plastic packaging and has strengthened the monitoring and reporting regime regarding marine litter under the Marine Strategy Framework Directive (2008/56/EC).

In Romania, policies on microplastics are still in their infancy, but are in the process of being aligned with EU legislation. To date, the measures include: the transposition of Directive (EU) 2019/904 on single-use plastics through Government Emergency Ordinance No. 6/2021, which bans the sale of certain plastic products; local initiatives regarding waste collection on the coast and in aquatic ecosystems, in collaboration with NGOs and local public administrations; the adoption of the National Strategy on the Circular Economy (2022), which provides for measures to prevent the generation of microplastics from industrial and textile processes. However, the lack of national standards for monitoring microplastics in water, sediments, and organisms, as well as the absence of advanced filtration systems in wastewater treatment plants, limits the effectiveness of the measures implemented. It is recommended that the issue of combating microplastics should be integrated into the National Recovery and Resilience Plan (PNRR) as a priority for public health and environmental protection.

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MARINE POLLUTION AND ITS IMPACT ON SURFACE AND SUBMARINE NAVAL OPERATIONS

Marine pollution transforms the ocean from a predictable environment into a technically hostile one, forcing naval forces to infiltration technologies and next-generation sensors capable of penetrating the contaminated environment. In this context, pollution, including that caused by microplastics, has an increasingly visible impact on the conduct of naval operations, affecting both surface ships and submarines.

Notable consequences include:

a) *interference with detection and monitoring equipment:* accumulations of microplastics and macro-debris can affect the accuracy of passive and active sonar systems used in the detection of submarines and sea mines; plastic materials in suspension alter the propagation of acoustic waves in water, contributing to increased background noise and reduced sonar detection resolution (Zhao et al., 2020);

b) *risk to intake systems and the cooling of ship propulsion systems:* plastic fragments and associated hull vegetation (biofouling) associated with them can block the intake systems of ship engine cooling systems, leading to an increased risk of overheating or unplanned shutdown of critical systems (Kühn et al., 2015);

c) *increased biofouling of ship hulls:* microplastics facilitate the formation of hull fouling, which acts as a substrate for the colonization of marine organisms, sometimes to an excessive degree, thereby increasing hydrodynamic drag and energy consumption in ships. For submarines, this phenomenon affects the acoustic signature and stealth capability (Lobelle, Cunliffe, 2011);

d) *strategic implications:* from a military perspective, pollution of the marine environment reduces the predictability and safety of operations in coastal zones or restricted maritime areas, where acoustic and environmental conditions become essential. Thus, the management of microplastic pollution is no longer just an ecological problem, but one with direct implications for maritime security and naval operational capability.

CONCLUSIONS

Contemporary oceanography demonstrates that the health of marine ecosystems is not merely an ecological issue, but rather a pillar of global security. Environmental degradation through pollution and climate change is redefining trade routes and response capabilities, transforming the ocean into a space for managing multiple risks.

Marine pollution, particularly that caused by microplastics and chemical residues, extends beyond the biological sphere and becomes a factor of operational constraint. Thus, both surface ships and submarines face new technical challenges, ranging from sonar signal interference to risks of mechanical damage, forcing the adaptation of defence technologies to an increasingly polluted environment. In this context, we believe that it is imperative to equip ships and submarines with high-performance cooling water filtration systems, thereby preventing damage caused by microplastics. As such, we believe that the protection of the oceans is inextricably linked to sustainable public health and effective strategic stability. In this regard, addressing current challenges requires close international cooperation that combines advanced scientific research with naval security policies to ensure the long-term sustainability of resources and the safety of navigation.

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There is a need for protected and monitored maritime routes, which would ensure tactical predictability for naval security operations and commercial shipping. We also believe it is necessary to implement surveillance networks that combine real-time oceanographic data (temperature, salinity, oil slicks) with traffic monitoring systems. It allows naval forces to avoid areas with a high risk of collision with floating debris or areas where sonar performance is degraded chemically. Last but not least, given the risks to public health and crew safety, it is recommended to implement rigorous protocols for testing water and air quality on board ships, to detect the presence of microplastics and volatile chemical compounds that can accumulate in enclosed spaces during long-duration missions.

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