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Exploring the Contribution of Artificial Intelligence in Combating Plastic Pollution in Oceans

Khandu Doma Bhutia, Pritam Sarkar and Saurav Kumar*

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Corresponding Author
Saurav Kumar
e-mail: saurav@cife.edu.in

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Abstract

Plastic pollution has emerged as a pressing global environmental concern, posing significant threat to ecosystem, marine life, and human health. Addressing these challenges requires innovative approaches, and the interaction of Artificial Intelligence (AI) as shown promise in tackling various aspect of marine litters. This article explores the concern related to plastic pollution, the impact of marine debris on the marine environment, and potential contribution of AI technologies in combating plastic pollution. The analysis encompasses AI-driven solutions such as image recognition, machine learning algorithms, and AI powered robotics for cleanup operations.

1. Introduction

Ocean pollution is a global issue and its worsening at an alarming rate. It is intricate intermingle of industrial waste, plastics waste, sewage, agricultural runoff, toxic chemicals and metals. Sources of pollution is majorly contributed from land-based sources accounting to 80%. There have been several negative impacts reported aligning to ocean pollution and its impact being worsened by global climate change. Plastics are ubiquitous to every environment due to its properties like durability, corrosion resistant and sorption of toxicants. Plastics fragments, microplastic (<5 mm in diameter) have come in limelight as they paved their way through the food chain acting as a vector for chemical transfer. The rate at which the microplastic has entered into food chain would not only have impact on physiology of an involved organism but transferring the flux of microplastic from aquatic system to terrestrial. The sea currently has 5.25 trillion plastic particles, weighing 298,940 tons, floating on it (Eriksen et al., 2014). Plastics are being transported by ocean current and winds throughout global marine environment. Fate of these plastics are either floating on surface, stranded on shores, or settle in sea bed. The rate of technological advancement is outpacing the traditional methods, one such technological tool which provides solution for

Author's Address
Aquatic Environmental Management, ICAR–Central Institute of Fisheries Education, Mumbai, Maharashtra (400 061), India

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environmental management is Artificial Intelligence (AI). Artificial intelligence and Machine Learning (ML) are synergistic in nature, in which the machine learning is used for understanding ocean, preventing marine disease outbreak, fishing, or preventing coral bleaching based on these, a machine/application tool AI can be developed to mitigate the marine pollution. The amalgamation of AI and ML helps in analyzing the big data more precisely, which enables forecasting and assessing the effect of plastic pollution. These technologies are game changing in the way we work and think.

2. Background Information

Industrialization has led to mountainous global environment issues. In the begging when plastic was first invented in 1950s the production was only 1.5 MMT but in 2021 the production was recorded 390.7 MMT (Statista, 2024). The models created for betterment of human society have predominantly achieved by detrimentally impacting our planet earth. It has been claimed that there are nine processes and systems which maintains the stability and regulates the resilience of our planet Earth. Out of which the four processes are deterioration of biosphere health, climate change, changes in globe's chemistry, and land-system change which have crossed the borderline due to human activity. Approximately 8 million tons of plastics enter into ocean annually, which equates to dumping a one garbage truck per minute. Ocean plastics have a great impact not only to the marine ecosystem health but to maritime natural capital. It has been forecasted that by 2050 the ratio of plastic to fish in the ocean (by weight) would increase (Anonymous, 2016).

The First Industrial Revolution which lasted around 1820 and 1840, had a distinguish transformation in human history where human and animal labour shifted into machinery which generated enormous economic, political and social changes. The Fourth Industrial Revolution where technologies have interconnected the three realms i.e, biological, digital and physical. The series of "Fourth Industrial Revolution for the Earth" has been crafted to show the potential and its application in meeting the environmental problems. Artificial Intelligence is the emerging technology of Fourth Industrial Revolution. Artificial Intelligence refers to computer systems which has the ability to perceive their surroundings, acquire knowledge, and act based on the processed information and their predefined objectives.

3. Plastic Pollution

3.1. Macroplastics

Plastic particle exceeding a diameter of 5 mm has been termed as "macroplastic". Packaging industry contributes to highest plastic production accounting to 39.9%. Macroplastics are distributed vertically and horizontally in the ocean via land-based and ocean-based pathways and redistributed due to ocean current, density-driven in high latitude and wind-driven at mid and low latitudes. Land-based sources are from coastal activities, wastewater effluent, river system, waste disposal contributing 80% and ocean-based source account for 20% resulted from lost fishing gear, sinking of ship, waste disposal directly from ships. About 90% of floating plastic debris is accumulated on the sea bed due to lose of buoyancy under bio fouling (Galgani et al., 2015). Trawling operation done by ICAR-CIFE, Mumbai on 13th November, 2023 reported notable amount of macroplastics in the catch from Mumbai coast of Arabian Sea (Figure 1).

Figure 1: litter collected by trawling in location (190 6.260'N, 72o 47.161'E)

3.2. Microplastics

Microplastics are fragments/particles of plastics ranging in diameter less than 5 mm. Microplastics are divided into two categories i) Primary microplastics, are those that have been produced directly for the use like microbeads in cosmetics, plastic fibres in synthetic textile. ii) Secondary microplastics, which have been formed due to fragmentation of macroplastics due to wind action, microbial degradation, UV radiation and wave action. Recent database indicates that around 358 trillion microplastics particles are present at the global ocean surface (Asher, 2023). Primary producers in ocean tend to aggregate with microplastics thereby reducing the photosynthetic activity. Recent study on effect of microplastics have shown that these tiny particles negatively affect the aquatic organisms of all trophic level. In fish microplastics reduced growth, cause immense stress. In case microalgae these smaller plastic particles inhibited the growth and reduced pigment content. In addition, the consumption of microplastics by zooplankton is a concerning issue, which has been reported in Indian Ocean and Yellow Sea and the evidence that microplastics transfer from lower to higher food chain level hinder the carbon cycle pattern.

4. Interaction of Plastic with Aquatic Organisms (Du et al., 2021)

Table 1: Effect of plastics on aquatic organisms

Organism	Interaction	Plastic type
Sea turtle (*Caretta caretta*)	Biofouled plastic releases odorants, stimulating foraging behaviour to marine debris	Macroplastic
Sea turtles	Plastic debris detected inside the in gut of both juvenile and adult turtle, which cause the death.	Macroplastic
Adélie penguin	Entangled in fishing lines and nets, Mirny east Antarctica	Macroplastic
Emperor penguin chicks	Green synthetic rope braided from fishing lines occupied the entire stomach volume, as on fed as food lump by adult penguin mother, causing death	Macroplastic
Seabird	Reduction in commensal microbiota and increase in pathogens and plastic-degrading microbes in gut of seabird	Microplastic
Antarctic krill (*Euphausia superba*)	Krill has the ability to fragment the ingested microplastic and release nanoplastics impacting other organisms	Nanoplastic (<1 um)
Commercial fisheries	Ingestion of plastic has doubled and it continues to increase at 2.4% per year	Macroplastic, Microplastic
Primary producer (algae)	Alter photosynthesis, growth, reduction of expression of chloroplast genes	Microplastic and nanoplastics

5. Artificial Intelligence

Artificial Intelligence (AI) is emerging as the cornerstone technology of the fourth industrial revolution, similar to the role of "electricity" of previous eras. The scope of AI in processing big data, increasing globe connectivity, enhanced computational procedures, rapidly evolving technologies has helped in establishing AI in vivo (in everyday use). The range of AI has expanded into i) minimum human intervention, example an automated machine capable of autonomously learning and sorting various recyclable household materials. ii) assisted intelligence, example revealing potential early indicators that signal the onset of hurricanes. iii) augmented intelligence, example management facilitated by AI in examining greenhouse gas emissions. In addressing the global environmental challenges like climate change, healthy ocean, conservation of biodiversity, clean air and weather and disaster resilience. AI has tremendous capacity to reveal solutions. Blue river technology is one of the solutions of AI to identify and detect the changes in biodiversity involving the existence of invasive weeds. Global fishing watch which enables the tracking of illegal fishing and prevent overfishing. For detecting pollution levels and observing variations in temperature and pH AI-powered robots such as robotic fish are employed. Ocean surface cleaning autonomous robot (OSCAR) it can be deployed to clean up oil spills, transmitting distress signals to the base station.

5.1. Use of AI in addressing plastic pollution

AI powered technologies for collection of debris: i) on destination: ocean clean-up project utilizes AI-assisted autonomous systems that roams in the ocean gyres autonomously to remove the garbage on ocean itself (Figure 2). Other debris collection projects that leverage AI are the Sea-next project, Jellyfishbot robot from IADYS. ii) Second step to prevent plastic pollution is removing the debris from source: Among Mr Trash Wheel, The Interceptor, The Manta, and the Bubble Barrier, the Interceptor which is sole known initiative employing AI. The interceptor operates based on renewable energy and has been effectively utilized in some countries like Indonesia, Malaysia, Vietnam (Agarwala, 2021).

Figure 2: Jellyfishbot by IADYS (Interactive Autonomous Dynamic System)

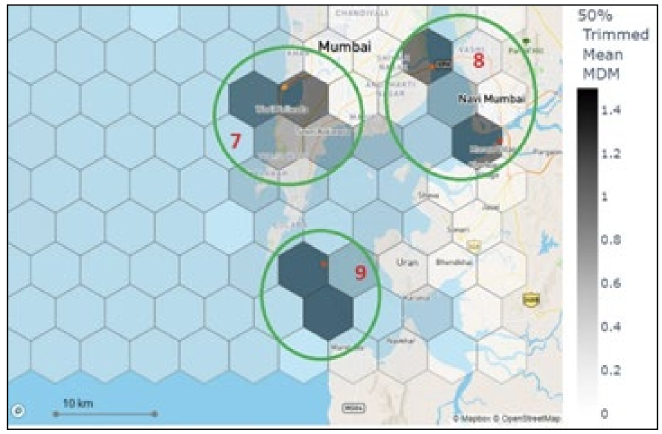

Figure 3: Marine debris and Suspected plastic (MD&SP) density map (Booth et al., 2023)

Plastic mapping: Using multispectral satellite imagery, the MAP-Mapper automated tool is employed to chart marine debris and suspected plastic (MD&SP) pollution. It records both the density of MD&SP and pinpoints the source locations. The researcher utilised the automated tool "MAP-Mapper" along with the enhanced Marine Debris Active (MARIDA) dataset for practical data analysis. One specific investigation took place in Mumbai, India, revealing that the areas with the highest density of marine debris and suspected plastic were identified as Mahim Bay, Thane Creek, Back Bay. MARIDA serves as a standard dataset used to develop and assess machine learning models designed to identify marine debris. MARIDA is the initial collection of multispectral Sentinel-2(S2) satellite data, that enables the differentiation marine debris from organic material, foam, waves, various water types (such as clear, turbid, sediment-laden). Research evidence has shown that the use of Unmanned Aerial System (UAS) alongside deep learning techniques. This combination has proved to be effective for quantifying the amount of marine litter (ML) present in the coastal zone through the generation of density map (Papakonstantinou et al., 2021) (Figure 3).

Autonomous Underwater Vehicle (AUV): It is a robotic device operated under the guidance of an onboard computer, enabling autonomous control and navigation in three dimensions within the aquatic environment. Data gathered by AUV sensors automatically georeferenced in both spatial and temporal dimensions. New AUV, "MARINE BIRD", employs a unique docking and self-recharging system which minimizes refueling eliminating resurfacing, demonstrating low time consumption and manpower. The efficiency of multiple AUVs surpasses that of a single AUVs in marine plastic clean up, therefore effective task allocation model is crucial for optimizing the role of these AUVs. Multi-Robot Task Allocation is the problem (MRTA), so to resolve it new MRTA model is tailored based on Location-Aided Task Allocation Framework (LAFF) method and evolutionary game theory (EGT). Deploying AUVs for deep sea cleaning signifies towards a better future. Employing multiple AUVs enhances cleaning speed, leveraging advance technologies. Recent advancements have replaced older system with more efficient and precise ones, rendering AUVs more reliable for ocean cleanup.

6. Conclusion

The persistent threat of marine plastic pollution demands innovative solutions. In confronting the pervasive issue of plastic pollution in our ocean, the integration of artificial intelligence and advanced technologies holds a significant promise. Harnessing AI powered technologies, particularly AUV, multi-spectral satellite imagery, the Interceptor etc. represents a significant advancement in combating this global challenge.

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