Another way to increase awareness about improving sustainable practice is through education, which Dr Mielgo is doing through the new masters she has developed in cancer biology where students have lectures on sustainability in science.

One of the biggest issues comes with energy consumption, Dr Mielgo told us, “In general people are good at switching off equipment, and just being diligent about house keeping things.” If she could give one bit of advice for students to take forwards, Dr Mielgo would argue that “the number one thing is diligence and keeping good track records and accurate protocols, because a lot of waste can be saved- plus the research becomes a lot better!”

Many thanks to Dr Ainhoa Mielgo for taking the time to sit down with us and discuss this topic.

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Plastic is a global menace

Do we have enough data?

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Plastic is a menace to the environment. It affects the ecosystems leading to loss of biodiversity and this indirectly affects human lives. Many studies have been done to try and understand their dynamics, but is this really enough? This study is about trying to estimate marine plastic debris locally in a city in India and was done through researching other related articles to investigate plastic debris growth rate in five years. Chennai is one of the most densely populated cities in the world and it is situated near the coast, making it one of the heaviest marine plastic debris producers. Plastic pollution has increased owing to the pandemic and the steps taken by the government to reduce it are not enough. Other factors adding to the plastic pollution are ghost fishing and microplastics, which are poorly understood. Both of these kill a lot of species making plastic one of the most dangerous threats to both ecosystems and human lives. This makes it important to reduce or stop the production of plastic immediately, and to find ways to reduce its harmfulness on the environment.

Abstract

Plastic waste ends up in the ocean through run-off and rivers which affects the marine ecosystem. Continuous increase in the production of plastics and polymers have exacerbated this problem. Here we report marine plastic pollution with reference to India and Chennai (the capital of Tamil Nadu, South India). In particular, Tamil Nadu has a long coastline and the plastic waste reaching it through rivers and land run-off, and dumped ghost fishing gear, causes serious problems to the flora and fauna as well as livelihood of the fishing communities across the region. Despite various studies, there remains an uncertainty about the quantity of macro and micro plastic waste reaching the oceans and the consequences of marine plastic pollution, locally as well as globally.

Introduction

Mass production of plastic began in the 1950s and has been increasing exponentially since (Villarubia-Gomez *et al.,* 2018). Of the total global production, about 1.5% to 4.1% ends up in the oceans (Wayman & Niemann, 2021). This estimates to 8 million tonnes of plastic debris that is discharged into the oceans every year (UNEP, 2018). Such a large discharge into the oceans affects the planet, causing loss of biodiversity as the marine organisms either ingest plastic or get caught on nets leading to death (Thomas *et al.,* 2019). It affects human health indirectly as we consume microplastics through the fish we catch (Senathirajah *et al.,* 2021). Loss of biodiversity leads to extinction of economically important species, thus bringing down a whole nation’s economy (Beaumont *et al.,* 2019). Marine biodiversity protection is a must for countries like India where a large part of the population depends on fisheries for their livelihood. It is imperative to understand the dynamics of marine plastic pollution and to keep record of the discharge of plastic into the ocean. For instance, plastic is discharged into the ocean through several ways including wind, surface runoff, rivers and littering, and can be classified as bio-based and fossil-based (Wayman & Niemann, 2021). Despite various studies, there remains an

uncertainty about the consequences of marine plastic pollution in Earth systems (Villarubia-Gomez *et al.,* 2018).

Marine plastic pollution in India

India is one of the major marine plastic debris contributors in the Indian Ocean. 8% of the total solid waste produced by India is plastic waste and Delhi, Kolkata and Ahmedabad are the top three cities contributing to the most pollution (Bhattacharya *et al.,* 2018). India produces about 9.46 million tonnes of plastic waste per year (Tripathi, 2020), a 39.7% increase in plastic waste production compared to 5.7 million tonnes production per year only five years ago (Verma *et al.,* 2016). Only 15% of the plastic waste produced is recycled in India (Kumar *et al.,* 2020). The rest is sent to landfills, incinerators, or emptied into the oceans and rivers. India disposes 0.6 million tonnes of plastic waste per year into the oceans directly or indirectly via rivers, surface run-off, wind and littering (Aryan *et al.,* 2019).

Rivers contribute to about 67% of the total marine plastic debris in the world (Lebreton *et al.,* 2017). Most of these rivers are from Asia and one of the top polluters is the Ganges in India. The Ganges originates from Western Himalayas and flows through four countries and discharges in the Bay of Bengal. The Ganges, the second most polluted river in the world (Lebreton *et al.,* 2017), discharges about 105,000 tonnes of plastic waste into the Bay of Bengal every year (Lechthaler *et al.,* 2021). Due to the heavy pollution of the Ganges, its biodiversity is rapidly declining. Pollution of this river affects human lives as well, decreasing fisheries and tourism and can lead to river contamination and spread of disease (Prata *et al.,* 2020).

Abandoned, lost or discarded fishing gear

Abandoned, lost or discarded fishing gear (ALDFG) is a serious problem worldwide as there is a lack of data. Most of these wastes are due to shipping or fishing accidents or bad weather, and while most of the lost fishing gear is retrieved by the workers, the little that remains causes serious problems to the marine ecosystems. Many species are killed by this waste, and since it does not decompose easily, it can continue to kill species. About 20% of all the plastic debris in the oceans is from ALDFG according to UNEP. Approximately 640,000 tonnes of ghost fishing gear is disposed into the oceans every year (Kaviarasan *et al.,* 2020). India has 174,000 units of fishing gear in operation, of which 154,008 units are gillnets/driftnets and 7285 units are traps while the remaining is fishing lines (Thomas *et al.,* 2019). Of these, 15,276 tonnes of gillnets are lost from India per year (FAO, 2020).

Marine plastic pollution in Tamil Nadu and Chennai

Tamil Nadu is a huge concern as it stands second in plastic waste production in India (Statista, 2019). Tamil Nadu contributes to 18% of the total plastic waste produced and disposed into the ocean by India which estimates to about 1.7 million tonnes per year of plastic waste production and about 108,000 tonnes per year disposed into ocean via rivers and direct littering (TOI, 2018). 57% of total plastic production is thin plastics mainly used for packaging while about 10% of production is for Polystyrene (PS), Polyurethane (PU), Polyethylene Terephthalate (PET) and Polyamide (PA) plastics (Wayman & Niemann, 2021). Plastics are made from non-renewable resources such as crude oil and hence they are hard to decompose as the polymers are bonded through covalent bonds, a strong bonding force. Due to such reasons, the Government of Tamil Nadu banned usage of thin plastic (polymers of thickness below 40 microns) (The Hindu, 2013). Despite such laws being passed, Chennai is the major cause of plastic production in Tamil Nadu as it produces about 898,700 tonnes of plastic waste per year of which 57,000 tonnes per year is disposed into the ocean (TOI, 2019).

The Adyar and Cooum rivers are the major contributors in Chennai as they discharge plastic into ocean through littering and flow transport (Jain, 2019). The Adyar river discharges about 9,200 tonnes of plastic waste per year and the Cooum river discharges about 2,200 tonnes per year (Ramakrishnan & Lakshmi, 2019) accounting for 81% and 19% of total river discharge from Chennai, respectively. Thermocol (32%), plastic bags (30%), bottles & caps (15%), straws (14%) and food wrappers (9%) comprise the majority of macroplastic debris (Figure 1a). Comparing these estimates with data collected from about five years ago, there is a 71.7% increase in plastic discharge into ocean from Chennai alone (Mallapur, 2014; The Pioneer, 2013). This alarming increase could be due to the increased usage of disposable plastics like masks,

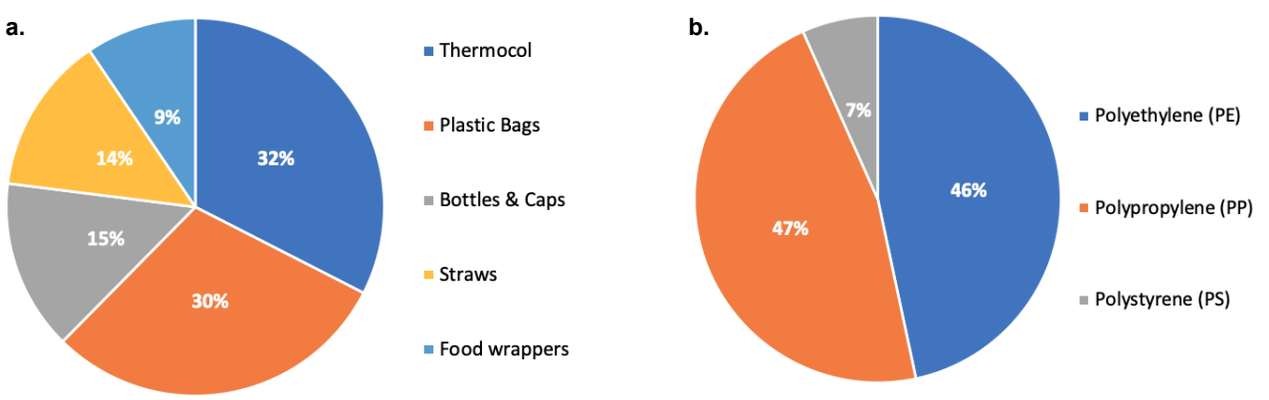

Figure 1a. Major Microplastic debris discharged by rivers in Chennai. **b.** Major polymers found in microplastic debris and their abundance.

COVID protection kits and home deliveries (plastic used for packaging is a major contributor to plastic waste).

Sea-based waste must also be taken into consideration. Tamil Nadu possesses various types of fishing boats, and they can be classified as traditional (catamaram, dug-out canoes, plank-built canoes, masula boats, dhinghi, outrigger canoes, built-up boats) and mechanical (hand line boats, pole and line fishing vessel, trolling vessel, dol netter, gill netter, stern trawlers) (TNAU, 2015) and the major fishing gear types include gillnets, hook and line, shore seines and boat seines (FAO, 1983). Chennai has 44,672 fishing crafts in total among which 5893 are mechanical boats, 32,879 are vallams and 5,900 are catamarans (Fisheries, 2018). No reliable sources are available to calculate the estimated ALDFG from Tamil Nadu and Chennai.

Microplastic

Microplastics are small plastic particles less than 5 mm in diameter, introduced into natural ecosystems through human influence or degradation from pre-existing microplastic transported through water systems (Lechthaler *et al.,* 2021). Microplastics are particularly hard to locate, track and study due to their microscopic size. Microplastics present another issue in that they show high affinity to other toxicants, increasing the danger for organisms that may ingest them (Gopinath *et al.,* 2020). The concentration and toxicity of ingested microplastics accumulate with increased trophic level. Of total plastic marine debris, 1% floats, 5% washes up on shorelines and only 6% is made up of microplastic (Kemkaran & Kumar, 2019). This makes it important to study microplastics and their dynamics.

Calculating the amount of microplastics entering the ocean can be challenging as they are small and the rate at which plastics degrade is unknown. Nevertheless, the abundance of microplastic from Chennai is found to be 309 ± 184 microplastic/kg of sediments (Satish *et al.,* 2019) and that from The Adyar river is 0.33 particles/l of water (Lechthaler *et al.,* 2021). The Adyar river discharges about 11.6 trillion microplastic particles into the Bay of Bengal per year (Lechthaler *et al.,* 2021). Such a large discharge causes harm to the natural ecosystems and inevitably affects humans too. Microplastic abundance was studied, and it was found that the polymers Polyethylene (PE) contribute to 46%, Polypropylene (PP) to 47% and Polystyrene (PS) to 7% of all the microplastics (Figure 1b) (Lechthaler *et al.,* 2021). About 64% are fibres, 22% films, 12% fragments and 2% pellets (Figure 2) and 44% of them were black, 30% red, 14% white (Lechthaler *at al.,* 2021). These are the types of microplastic discovered in the natural ecosystem so far. Studies are made to assess all the microplastics and their degradation systems to determine the major causes for discharge and to try and reduce their impacts.

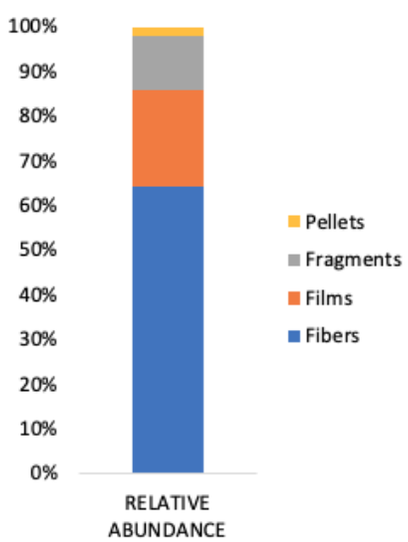

Figure 2. Morphology and relative abundance of microplastics.

Ocean accounting

Ocean accounts link marine and coastal environment related social circumstances to economic activity through a structured compilation of consistent and comparable information (Global Ocean Accounts Partnership, 2019). This has been brought to light recently, and hence not a lot of studies are available. Ocean accounting can simply be defined as the interaction between the economy and the environment, the exchange of stocks and the benefit to people affected by social and governance factors (Global Ocean Accounts Partnership, 2019). Ocean accounting is rather hard to obtain in India due to many factors, mainly the underestimation of marine plastic debris. This underestimation leads to the loss of biodiversity and extinction of economically important marine species unmonitored and unaccounted. India's total marine species diversity is 16,720 (Joshi & Varsha, 2018), containing about 7.28% of all marine diversity on Earth, out of which nearly 700 species are affected by plastic (Parker, 2019). 90% of the species lost due to ghost fishing alone are commercially important (WWF, 2020). This leads to about 1 – 5% loss in marine ecosystem services leading to $500 - $2500 billion loss (Beaumont *et al.,* 2019). The economic costs come to about $3300 - $33000 per ton of marine plastic per year (Beaumont *et al.,* 2019).

Using the above information, the economic loss due to marine plastic pollution in some of the top polluting countries are; China (3.53 Mt): $11.65 - $116.5 billion loss per year, Indonesia (1.29 Mt): $4.26 - $42.6 billion loss per year, Philippines (0.75 Mt): $2.48 - $24.8 billion loss per year, Vietnam (0.73 Mt): $ 2.41 - $24.1 billion loss per year, Sri Lanka (0.64 Mt): $2.11 - $21.1 billion loss per year and India (0.6 Mt)\; $1.98 - $19.8 billion loss per year approximately (McCarthy, 2020).

Conclusion

Plastic pollution is a concerning issue as consumption and discharge have increased but no steps have been taken by India to study, monitor and reduce plastic usage. Some of the states provide no data on plastic waste discharge and the ones that do have an underestimated value due to immense illegal dumping along the riverbanks by citizens. Little to no effort was made to educate citizens about plastic littering and its effects on ecosystems and humans. This has immense impacts on the marine ecosystem, especially because only 15% of all plastic waste produced

in India is being recycled (Kumar *et al.,* 2020). 66% of marine mammals, 50% of birds and all turtles are affected by the marine plastic debris worldwide (WWF, 2020). Almost 90% of the species dying due to ghost fishing are commercially important (WWF, 2020) and 17% are near threatened species (Raha *et al.,* 2020). Effective evaluation of prevention of plastic pollution in the marine environment and monitoring programs should be tailored to plastic policy interventions (Harris *et al.,* 2021). Plastic production and consumption must be reduced, and the laws passed must be monitored regularly to safeguard the marine ecosystems and the lives of people depending on it.

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