Systematic Meta-analysis of Microplastic Concentrations in Aqueous Ecosystems

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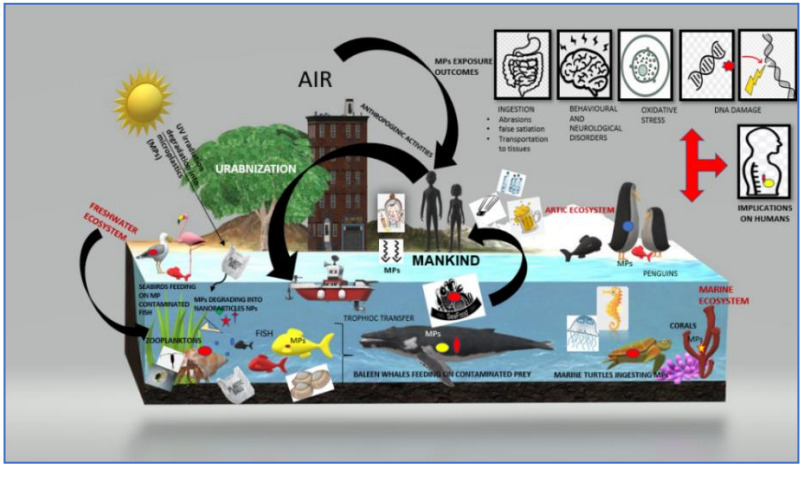
Graphical Abstract



Abstract

Background

Micro- and nano- sized plastic particles have given rise to a newfound curiosity among researchers as they are gathering steam in terms of its potential human and environment health hazards. The discovery of plastic particles of the micro-scale sizes, in the ‘pivot of change era’ of the early 1970s, led to the genesis of the term ‘Microplastics (MPs)’ which was hypothesized to contribute towards the emerging threats

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of environment and human health. Apart from the reports of around 690 marine species being contaminated by MPs up till now, there are also recent records of MPs presence in table salts (> 100 brands), drinking water (both tap and bottled), branded milk, beer, seafood, canned sardines, tea bags, meat packaging, take-away food containers, market cooked rice and inevitably in air with an estimated human body burden of (0–3.0) $\times 10^7$, (0–7.3)$\times 10^4$ and (0–4.7)$\times 10^3$ items per person per year through inhalation, consumption of table salt and drinking water respectively. With such an interminable, quinquagenarian surge of MPs now, we have managed to score 8.3 billion metric tons of the world-wide volume of plastics. The infiltration of MPs in the water systems is majorly the result of anthropogenic activities of mankind at individual as well as community level. The domestic runoff in the form of fibers, microbeads, and differential fragments of MPs from cosmetic and other household consumer products, becomes the main cause of aquatic exposure in the present times. Besides, the uncontrollable degradation of the larger plastic items, releases from the manufacturing industries (pellets and resin powders from air-blasting) severe the menace. Fishing, tourism, recreational activities also contribute significant primary pathways of exposure leading to marine and freshwater organism's susceptibility to MPs. However, the studies have been reporting toxicities of MPs at unrealistic concentrations which are not likely in near future based on the analysis of the current reported MPs concentrations from across the world in surface water, sediments as well as the organisms.

Objective

We carried out a systematic meta-analysis to analyse the concentrations of microplastic from environmentally occurring field samples (like water, sediment and organisms) and the concentrations

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employed under laboratory settings in order to have a comparative interpretation among the severity of exposure and resultant toxic effects among the organisms.

Methodology

In this work, a total of 201 data points including environmentally occurring MPs and concentrations of MPs in laboratory settings have been analysed towards constructing a severity Index based on the concentrations of MPs and thereby clearing the risk picture associated with it. The reported environment and laboratory concentrations have been compared to interpret the reality behind the MP pollution and the hazard it poses to the environment.

Key Findings

Among the 100 incidences of MPs concentration in laboratory, 22 points had concentrations lying below the highest reported environmental concentration i.e., 1.54E+08 MPs/m3. An in-depth search of the MPs related available literature lead us into formulating a Hypothesis as: The severity of the MP toxicity increases with increasing number of particles and decreasing size. The lowest environmentally occurring concentration of MPs was found to be reported in the Gulf of Maine in the United States by Law et al., (2010), with an abundance of around 0.001particles/m^3 while the highest environmental concentration of the MPs was in the European snow (1.54E+08 MPs/m^3) comprising mainly of varnish, rubber, PE, and PA which was calculated to be about 4.42E+11 fold lesser than the highest reported laboratory concentration of about 6.80E+19 MPs/m^3 that has been used to assess MPs toxicity in primary producers using *Skeletonema costatum* model system. Most of the lab experiments were conducted at approximately 4.17E+11-fold higher MPs concentrations compared to environmentally relevant

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concentrations. Among the total of 100 studies done under laboratory settings, only 22.0% lie under the reported field concentration. The average reported concentrations from field studies and laboratory exposure studies were found to be 1.90E+06 MPs/m^3 ± 1.54E+07 MPs/m^3 and 7.92E+17 MPs/m^3 ± 6.82E+18 MPs/m^3 respectively. Around 1.54E+08 MPs/m3 and 2.00E-03 MPs/m3 was the maximum and minimum reported MPs concentration from the selected data points in the present investigation. However, there are still some voids in the environmental MPs data in terms of the spatial concentrations in a given time, as many areas are still unexplored for their MPs loads. Based on the analysis, we made MPs concentration index scale to have toxicity criteria noticed among the organisms under *in situ* and lab conditions.

Conclusion & Recommendations

Microplastics have been found to be present in the natural environments and are notorious of their harmful lingering effects on the biota. Scientific communities have targeted and identified MPs and have demonstrated their detrimental effects on a range of organisms both from the aquatic and terrestrial ecosystems. However, the concentrations of the MPs used in such extrapolatory studies was found to be many folds higher than what has been reported from the environmental matrices leading to a confused status of MP adversities. There is hence a huge need for the standardization of the exposure units and concentrations as well as the adoption of guidelines for regulated experiments on MPs, as the cumulative number of laboratory trials might pose as another pathway for MPs exposure to the untargeted populations through inadvertent disposal practice. Hence it is recommended to consider the future work based on reported concentrations in the environment for assessing the risk associated with MPs. This will provide a sustainable development goal

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for the developing countries in tackling the MPs menace and precise risk assessment strategy in regulatory point of view.

Biography

Dr. Anbumani Sadasivam is a senior scientist in the Division of Ecotoxicology at CSIR-Indian Institute of Toxicology Research (Government of India).

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