MICROPLASTIC POLLUTION: CAUSES, EFFECTS AND CONTROL

Editors:

Rahul Singh

Neeta Raj Sharma

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Microplastic Pollution: Causes, Effects and Control

Edited By

Rahul Singh
School of Bioengineering and Biosciences
Lovely Professional University
Punjab, India

&

Neeta Raj Sharma
School of Bioengineering and Biosciences
Lovely Professional University
Punjab, India

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Editors: Rahul Singh and Neeta Raj Sharma

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CONTENTS

FOREWORD

Since the time plastics became an inseparable part of our daily life, we have produced unbeatable 8.4 billion tons of plastics. Rivers are contaminated with more than 2.4 million tons of synthetic polymers including microplastics. The term ‘‘Microplastic’’ was first coined in 2004 by Richard Thompson, a marine biologist. Plastic particles within the size range of 5mm – 1 µm are considered microplastics, whereas particles less than 1 µm have been termed as nano-plastics. Polyethylene, polypropylene, polyethylene terephthalate and polyamides comprise the majority of polymer types. These plastic particles can act as carriers of other toxic environmental contaminants such as, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), plasticizers, pesticides, heavy metals, pharmaceuticals, and poly-fluoroalkyl substances, like perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS). We are not talking about their presence in just rivers and oceans; these plastic particles are present in much of the air that we breath, the water that we drink, and the food that we eat. In a recent report, the U.S. Geological Survey titled bluntly, “It is raining plastic”, researchers describe how they found plastics in 90 percent of the rainwater samples. In this special issue on, ‘Microplastic Pollution, Causes, Effects and Control, Professor Neeta Raj Sharma, and associates’, describe the source of microparticles (MP), analytical techniques for the determination of MPs, and the impact of MPs on flora, fauna, aquatic and soil environments, with an example of their possible ill effects on human health. The publication of this comprehensive monograph is timely and will be well received by the scientific community.

Gundu H. R. Rao
Institute of Engineering Medicine, and Lillehei Heart Institute
University of Minnesota
Minneapolis, Minnesota
USA

PREFACE

In today's time, microplastic is known as an emerging pollutant. It was first recognized in an ocean, but as the search and analysis continued, it was claimed to be present in fresh water, groundwater, soil and even in the air. Microplastics in the environment can be of two types, the primary source which is made intensively in cosmetic products and the secondary source which is formed due to the degradation of plastics. As the search is increasing, the amount of degraded plastic and the negative impact seem to be increasing.

There is a lot of confusion about the name of microplastics, because its size starts from < 5 mm. Like its name, its sampling and analysis are also quite complex. As far as the impact is concerned, it is not only harmful in itself, but it also takes the form of a multiple-stressor by accumulating many hydrophobic contaminants in the water.

The editors would first like to thank all contributing to this important topic. We, thank you to Nafiaah Naqash who contributed significantly to the compilation of this book. We also thank the publication team wholeheartedly, from whose side we got full support, and the result is in front of you in the form of this book.

Rahul Singh
School of Bioengineering and Biosciences
Lovely Professional University
Punjab, India

&

Neeta Raj Sharma
School of Bioengineering and Biosciences
Lovely Professional University
Punjab, India

List of Contributors

Arun Karnwal	Department of Microbiology, School of Bioengineering and Biosciences, Lovely Professional University, Phagwara-144411, Punjab, India
Dhriti Kapoor	Department of Botany, School of Bioengineering and Biosciences, Lovely Professional University, Phagwara (Punjab), India
Dhriti Sharma	Department of Botany, School of Bioengineering and Biosciences, Lovely Professional University, Phagwara (Punjab), India
Francesco Fazio	Department of Veterinary Science, University of Messina, Messina, Italy
Gautam Priyadarshi	Department of Earth & Environmental Science, KSKV Kachchh University, Bhuj-370001, Gujarat, India
Harpreet Kaur	Department of Chemistry, Lovely Professional University (LPU), Phagwara, 144411 Punjab, India
Imtiaz Ahmed	Fish Nutrition Research Laboratory, Department of Zoology, University of Kashmir, Srinagar-190006, Jammu and Kashmir, India
Inderpal Devgon	Department of Microbiology, School of Bioengineering and Biosciences, Lovely Professional University, Phagwara-144411, Punjab, India
Ishtiyaq Ahmad	Fish Nutrition Research Laboratory, Department of Zoology, University of Kashmir, Srinagar-190006, Jammu and Kashmir, India
Khushboo	Department of Microbiology, School of Bioengineering and Biosciences, Lovely Professional University, Phagwara-144411, Punjab, India
Kuljit Kaur	Department of Chemistry, Lovely Professional University (LPU), Phagwara, 144411 Punjab, India
Manpreet Kaur Somal	Department of Biotechnology, School of Bioengineering and Biosciences, Lovely Professional University, Phagwara-144411, Punjab, India
Monita Dhiman	Khalsa College for Women, Civil Lines, Ludhiana, Punjab, India
Mrugesh Trivedi	Department of Earth & Environmental Science, KSKV Kachchh University, Bhuj-370001, Gujarat, India
Mukesh Kumar	Department of Microbiology, School of Bioengineering and Biosciences, Lovely Professional University, Phagwara-144411, Punjab, India
Nafiaah Naqash	School of Bioengineering and Biosciences, Lovely Professional University, Phagwara-144411, Punjab, India
Perumal Muthukumar	Department of Geology, V.O. Chidambaram College, Tuticorin-628008, Tamilnadu, India
Quseen Mushtaq Reshi	Fish Nutrition Research Laboratory, Department of Zoology, University of Kashmir, Srinagar-190006, Jammu and Kashmir, India
Rahul Singh	School of Bioengineering and Biosciences, Lovely Professional University, Phagwara-144411, Punjab, India
Reetika Rani	School of Bioengineering and Biosciences, Lovely Professional University, Phagwara-144411, Punjab, India

Rohan Samir Kumar Sachan	Department of Microbiology, School of Bioengineering and Biosciences, Lovely Professional University, Phagwara-144411, Punjab, India
Ritu Bala	Department of Microbiology, School of Bioengineering and Biosciences, Lovely Professional University, Phagwara-144411, Punjab, India
Sekar Selvam	Department of Geology, V.O. Chidambaram College, Tuticorin-628008, Tamilnadu, India
Sadguru Prakash	Department of Zoology, M.L.K. (P.G.) College, Balrampur, UP, India
Sagar Prajapati	Department of Earth & Environmental Science, KSKV Kachchh University, Bhuj-370001, Gujarat, India
Sarabjeet Kaur	Mehr Chand Mahajan DAV College for Women, Sector- 36, Chandigarh, India
Savita Bhardwaj	Department of Botany, School of Bioengineering and Biosciences, Lovely Professional University, Phagwara (Punjab), India
Suraya Partap Singh	Department of Zoology, Government Degree College Kathua, Kathua, Jammu and Kashmir, India
Tunisha Verma	Department of Botany, School of Bioengineering and Biosciences, Lovely Professional University, Phagwara (Punjab), India

CHAPTER 1

Tools and Techniques to Analyse Microplastic Pollution in Aquatic and Terrestrial Ecosystems

Gautam Priyadarshi[1], **Sagar Prajapati**[1] and **Mrugesh Trivedi**[1,*]

[1] *Department of Earth & Environmental Science, KSKV Kachchh University, Bhuj-370001, Gujarat, India*

Abstract: The estimation of microplastic pollution in the terrestrial and aquatic ecosystem is carried out by quantification and identification of the contaminated environment. Microplastic estimation consists of various steps such as sampling, visualization and quantification. Generally, the planktonic net, bongo net, manta net, and neuston net have been used for water sampling. While, grab samplers, tweezers, tablespoons, trowels, shovels, spatulas, or hand picking methods have been used for soil and sediment sampling. The biological sample from the study sites comprises the direct collection of the whole organism or its colony as a sampling unit. However all samples are required to be processed further to extract the microplastic using techniques such as filtration, density extraction, digestion, and magnetic & electrostatic extraction. The digestion method is used for direct characterization such as thermal gravimetric analysis. The identification of microplastic is based on microscopic images which provide the shape, size, colour, and texture of the microplastic surface. Visual identification using microscopes is time-consuming and susceptible to human error as well as a risk of misidentification, which leads to underestimation or overestimation of microplastic pollution. Spectroscopic methods such as ATR-FTIR, μ-FTIR and Raman spectroscopy provide identification and quantification of synthetic polymer. Advance combined analytical techniques have been reported during the last few years such as portable micro-Raman, SEM-FTIR, Pyr-GC-MS, TGA-DSC, and PEE. Priority and care are essential concerning the sampling, storage and handling microplastic samples for the QA/QC for accurate analysis. The present chapter aims to provide a comprehensive overview of the current knowledge of tools and techniques used for microplastic inquiries from an environmental sample.

Keywords: Aquatic ecosystem, Biota, Density extraction, Environment, Extraction, Electrostatic separation, Filtration, FTIR, Grab sampler, Identification, Magnetic extraction, Microplastic, Planktonic Net, Pyr-GC-MS, QA/QC, Quantification, Raman spectroscopy, SEM, Sampling, Sediment, Sample processing, Terrestrial ecosystem.

* **Corresponding author Mrugesh Trivedi:** Department of Earth & Environmental Science, KSKV Kachchh University, Bhuj-370001, Gujarat, India; E-mail: drmrugesh.trivedi@gmail.com

Rahul Singh and Neeta Raj Sharma (Eds.)

INTRODUCTION

Plastic pollutants with a fragment size of less than 5 mm are called Microplastics (MPs). They are caused by the physical or chemical degradation of several types of plastics in both aquatic and terrestrial ecosystems [1, 2, 3]. The first report on MPs in the marine ecosystem was found in 1972 with two different polymers including dine rubber and polystyrene. After this event, to date, MPs have been reported throughout the world (192 countries) however, only 44 countries have researched related to MPs. They have been found from various environmental samples including terrestrial and marine-based processes, including domestic and industrial drainage [4], maritime activities agricultural runoff [5] and wastewater treatment plants (WWTPs) effluent [6, 7]. Many recent investigations have revealed that MP pollution has come into our food, sea salt [8] and potable water as well [5, 9, 10]. Increasing MP pollution poses a risk to humans and the environment. The global oceans have also been littered with microplastic pollution as shown in Fig. (**1**). There are various levels of MPs's environmental exposure through ingestion of food, breathing air and dermal contact with textile and dust particles from the air. This may cause health issues [11]. Due to the MPs exposure to the environment, all the ecosystems may cause toxicity including oxidative stress, inflammatory lesions and increased risk of neoplasia *i.e.* abnormal growth of cells or tissues [12]. Therefore, the assessment of MP based on its types and abundance in each sphere of the environment is necessary. In this context, the challenge is to undertake a scientific investigation to minimize ambiguity in risk assessments of known or expected impacts of MPs to develop adequate strategies for its control. There are various analytical techniques including Imaging (to determine the shape, size colour, and texture) and spectroscopy (to identify chemical components/composition) that have been used to estimate the characterization of MPs [13]. Various studies have been published regarding the tools and techniques to analyse microplastic pollution from terrestrial and aquatic ecosystems [6, 14]. The various aspects of MPs analysis such as sample collection, handling, storage, processing, extraction, characterization and quantification of MPs from various components of the environment are discussed in the chapter. To avoid misidentification and reduce or avoid the cross-contamination of MPs during the various stages of analysis, quality assurance and control (QA/QC) is also mentioned along with some recommendations.

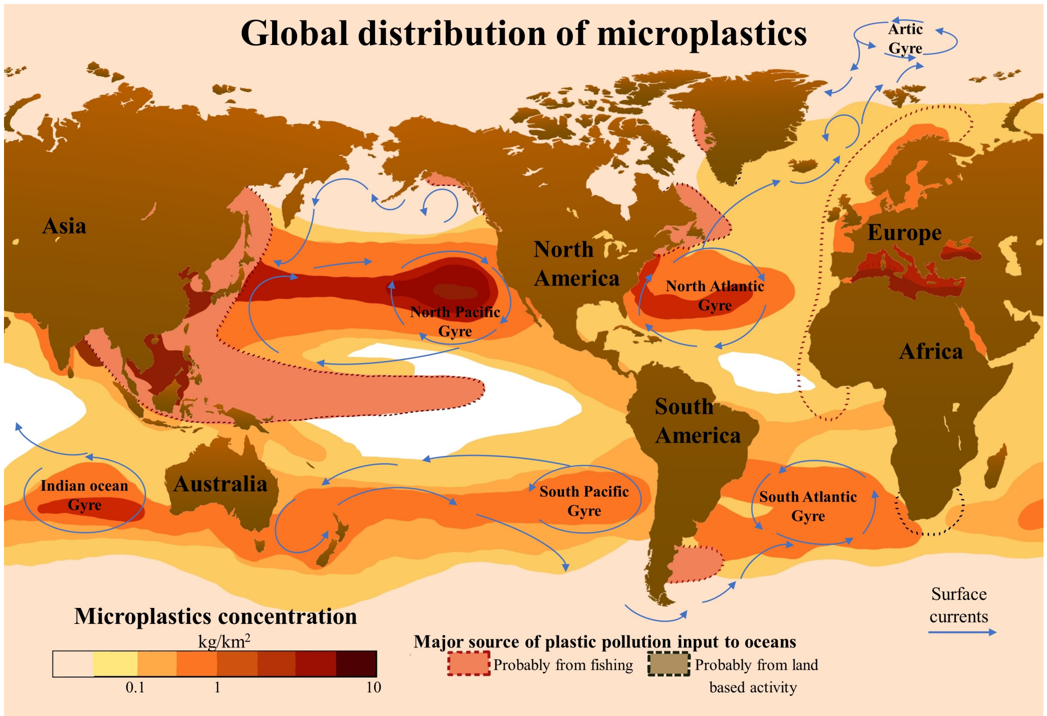

Fig. (1). Global distribution of microplastics in oceans. (Redrawn from "Marine Litter Vital Graphics").

SAMPLING OF MPs

There are mainly three approaches for sample collection including selective samples, bulk and volume-reduction. Selective sampling in which, items visible to the naked eye are directly extracted from the environment, such as on the surface of the water or sediment. This approach is simpler, however, there is a drawback that it is more obvious and sometimes heterogeneous types of particles and fibres are ignored because they are in a mixture with beach debris and other living organisms [15]. It is usually used at beaches and lakeshores [16]. Bulk sampling is the method in which the entire sample is taken without reducing its volume. When the sample size is too large, it is not possible to reduce the volume of the sample or identification of MPs is not possible through the naked eye, it is a more suitable technique. The majority of the biological samples are collected using this method [17, 18]. Sometimes, this sampling method is not representing the entire population but provides only a portion or a bunch of the population. To overcome this problem of sampling representation, volume reduction sampling method is being used to cover a large area. It reduces the volume of the entire population (bulk sample) until only the specific items of interest for further analysis remains.

CHAPTER 2

Occurrence and Source of Microplastic in the Environment

Sarabjeet Kaur[1,*] and **Monita Dhiman**[2]

[1] *Mehr Chand Mahajan DAV College for Women, Sector- 36, Chandigarh, India*

[2] *Khalsa College for Women, Civil Lines, Ludhiana, Punjab, India*

Abstract: Microplastics are ubiquitous on the earth, even in the purest environments like arctic snow, inaccessible mountains, *via*. Microplastics may be disseminated *via* air fallout near metropolitan areas, however, the great bulk of data points to water as the primary distribution channel. Researchers have discovered that surface and groundwater are also polluted by microplastics, despite maximum research focusing on marine pollution. The international community visualizes a decline in the concentration of floating plastic waste as an essential step toward the long-term sustainability of the seas. However, there is presently no universally acknowledged indicator of floating plastics trash density. Ultimately, a significant portion of the present microplastic proliferation has been attributed to wastewater, which is frequently not efficiently treated to eliminate such tiny, hydrophobic pollutants. Previously treated wastewater is discharged into water bodies, which in turn feed natural water reserves. Microplastics are also dispersed into the soil and terrestrial ecosystems by certain communities that irrigate their crops with wastewater. A further problem is that micro plastic-rich sludge from wastewater facilities is used as a fertilizer for food crops. It is crucial to keep an eye out for new developments in bioplastics and biodegradable polymers that avoid the build-up of microplastics in the food and agriculture industries.

Keywords: Atmosphere, Bioplastic, Biosphere, Distribution, Freshwater, Hydrosphere, Infiltration, Lithosphere, Marine, Microplastic, Nanoplastic, Occurrence, Plastic footprints, Pollution, Primary source, Secondary source, Sewage, Sources, Ubiquitous, Weathering.

INTRODUCTION

The extensive production of synthetic plastic commenced in 1907. Since then, plastic has become an integral part of global life. Plastics are in great demand because of their adaptability, resistance to corrosion, high strength-to-weight

* **Corresponding Author Sarabjeet Kaur**: Mehr Chand Mahajan DAV College for Women, Sector- 36, Chandigarh, India, E-mail: jatindersarab@gmail.com

Rahul Singh and Neeta Raj Sharma (Eds.)

ratio, low thermal and electrical conductivity, durability, and cheap production cost. As a result, plastic is used in a wide variety of goods, ranging from paper clips to spaceships. Between 1950 and 2015, around 6 billion tonnes of plastic waste were generated from an estimated 8 billion tonnes of produced plastic. Of this, 79% [1] still remains on the earth occupying terrestrial, freshwater, or marine ecosystems. By 2018, around 380 million tonnes of plastic have been added to the world's oceans [2]. Since the pandemic breakout, the amount of plastic garbage generated globally is expected to have increased to 1.6 million tonnes per day, owing to medical waste leaving plastic environmental footprints [3]. Global plastic production is expected to be bifold within two decades [4]. Approximately 6% of the oil produced in the world is consumed for the synthesis of plastic polymers [5]. Therefore, plastics and greenhouse gas emissions are intricately connected from manufacture to dumping, contributing to climate change [5 - 7]. It has been reported that greenhouse gas emissions from plastics worldwide [8, 9] have recently gained attention because of their deleterious effects on the climate. The greenhouse emission is intended to approach 1.34 gigatons annually by 2030 and 2.8 gigatons annually by 2050. On the other hand, plastic is a relatively recent and rising concern to ecosystems compared to other problems, including climate change, global warming, ocean acidification, land-use patterns, pollution, and invasive species. As a result, modern ecosystems will frequently be confronted with a cascade of accumulated stresses in the future.

The manufacture of synthetic plastics derived from fossil fuels continues to grow, but indigent waste management has resulted in stringent pollution problems. Microplastics have been found in coral reefs [10] marine sediments [11], urban and rural regions [12], freshwaters [13], and seawaters [14]. The majority of findings indicate that microplastics accumulate in aquatic ecosystems and their breakdown by products resulting in increased exposure of existing species to microplastics [15, 16]. A recent study on microplastics has focused primarily on the marine environment. Microplastics' implications, particularly in freshwater and soil, are still in their infancy, and significant gaps persist.

SOURCES

Microplastics infiltrate our ecosystems in a variety of ways and from divergent sources. Emissions from industrial and sewage facilities as well as agricultural land runoff are among the pollutants that can contribute to microplastics in the environment. Certain microplastics are designed exclusively for use as abrasives in industry or in personal care items such as exfoliants. As the name suggests, these are made with purpose and are the first generation of microplastics so-called primary or intentional microplastics [17]. To put it another way, secondary microplastics include those formed by the breakdown of more oversized plastic products, such as automobile tyres and synthetic textiles [18] that wear and tear, or as city dust (a collective term for particles produced by synthetic material linked with metropolitan areas) [19, 20]. Once in the ecosystem, plastics and microplastics may circulate through terrestrial, freshwater, and marine environments in cycles.

Primary Source

Primary microplastics, as described by Cole and colleagues [21], are characterized as plastics made that are tiny in size and derived from industrial and household items [22, 23]. Most often, they are utilized in air blasting media [24], face cleansers and cosmetics, as well as in medicine for drug delivery [25]. However, even though contemporary wastewater treatment practices can eliminate up to 99 percent of microplastics, the amount of microplastics discharged into the environment through effluent remains considerable [26].

A form of primary microplastic that has received the most attention is scrubbers, used in products such as exfoliating hand cleansers and face scrubs to remove dead skin cells. In the 1980s, the usage of microplastic scrubbers rose considerably as cosmetic businesses patented these items. The size, shape, and content of the particles vary depending on the type of cosmetic (Fendall and Sewell, 2009); for example, polyethylene and polypropylene granules (<5 mm) as well as polystyrene spheres (<2 mm) have been discovered in the same cosmetic product. Primary microplastics are explicitly created for their utility in personal care products, such as resin pellets and exfoliants [21, 27, 28].

Microplastics are present in varying size fractions across the world's coastal regions and aquatic ecosystems as a result of transport phenomena such as wind and ocean currents. Microplastics have a positive correlation with human population density [29]. Browne [18] conducted a survey of microplastic pollution around shorelines and discovered that one of the primary origins of microplastics in the oceans was sewage contaminated by fibers from washing clothing [30], as marine sediments were comparable to those used for textiles [29,]. These sources account for 35% of all sources [31].

Worldwide, wastewater treatment projects are also a significant contributor to microplastic discharge [18, 32, 33]. While bulky plastic particles are eliminated effectively during wastewater treatment, microplastics frequently circumvent treatment units [32, 34], infiltrating and accumulating in the aquatic environment [35]. Notably, a significant count of water treatment plants are positioned near the ocean creating a significant source of microplastic emission.

CHAPTER 3

Impact of Microplastics on Flora and Fauna

Quseen Mushtaq Reshi[1], **Imtiaz Ahmed**[1,*], **Ishtiyaq Ahmad**[1] and **Francesco Fazio**[2]

[1] *Fish Nutrition Research Laboratory, Department of Zoology, University of Kashmir, Srinagar-190006, Jammu and Kashmir, India*

[2] *Department of Veterinary Science, University of Messina, Messina, Italy*

Abstract: Microplastics are the compound class of greatly altered, synthetic particulates, which pollute wide-ranging types of environments. Being an impending source of concern owing to wide variability in their size range makes them potentially dangerous at all trophic levels. Numerous studies have studied the harmful effects of microplastics on the biota. The present study aims to compile information about the effect of microplastics on various species belonging to different taxonomic groups as reported from different parts of the world based on which, a general overview has been generated which clearly emphasizes that substantial efforts are required to deeply investigate the abundance, distribution and effects of microplastics on the flora and fauna of both terrestrial as well as aquatic ecosystems. However, the influence of microplastic contamination on human health and plants has received less intention. The knowledge derived from various studies clearly indicates that in order to safeguard our environment from the deteriorating effects of microplastics, we need to thoroughly control the amount of plastic production. Moreover, stress should be laid to make more use of bio-degradable products so as to minimize the demand for these plastic materials. Also, there is a dire need to aware the masses about the harmful effects of microplastics and the adoption of such policies at the global level which formulate a strong action plan for solid waste management so as to alleviate microplastic pollution, which otherwise could threaten ecological balance as well as harm the health and survival of various species.

Keywords: Aquatic organisms, Contamination, Human health, Microplastics, Plants, Pollution.

INTRODUCTION

The earth is persistently facing numerous threats by virtue of natural disasters and pollution caused due to anthropogenic activities [1]. Almost all natural resources are badly affected due to the frequent changes present in the environment.

* **Corresponding Author Imtiaz Ahmed:** Fish Nutrition Research Laboratory, Department of Zoology, University of Kashmir, Srinagar-190006, Jammu and Kashmir, India E-mail: imtiazamu1@yahoo.com

Rahul Singh and Neeta Raj Sharma (Eds.)

However, the aquatic ecosystem gets more affected due to all these changes in the form of water pollution [2, 3]. Plastic and microplastic pollution, along with associated nanoparticles, is one of the 'emerging' concerns in the mind of scientists at the moment [4]. Among them, microplastics are presently considered a hidden/silent agent that badly affects many aquatic organisms, therebaffectinged the food chain/web. Microplastics are defined as microscopic-sized plastic materials with a diameter of less than 5mm, which largely arise from parts of larger plastics directly released into the environment as production of personal care, UV radiation and mechanical degradation of plastic bags, bottles, food wrappers, *etc* [5]. Microplastics represent an obstinate environmental issue because of their existence in aquatic as well as terrestrial ecosystems, and the difficulty in detecting these items [6, 7]. The microplastics are actually made of a multifarious congregation of units having different sizes, shapes, densities, colours and chemical entities, which could have significance on their transportation methods and subsequent destinies in aquatic surroundings [8]. So, the question is how microplastics are formed in the aquatic environment. The answer would be it could be due to the direct source in the form of waste release from industries or an indirect source like wind and rain that cause deposition of piled wastes from houses that eventually end up into the water bodies and finally enter into the oceans [9]. Microplastics are sub-divided as primary and secondary forms. Primary microplastics refer to such materials which arise directly because of the usage of such products or materials which are made up of microplastics as their components. Secondary microplastics are those which are made as a result of the disintegration of plastics of larger sizes [6, 10]. Infiltration of microplastics into multiple ecosystems elevates concerns of their potential toxicity thereby causing harm to both flora and fauna. SAPEA (2019) report indicated the qualitative information and summarised the presence of microplastics in wastewater, drinking water, freshwater, estuarine, coastal and marine environments, besides air, soils, biota as well as food [11]. However, it further suggested that there is a need to understand the precise quantitative presence of microplastics in the atmosphere, soil and the marine water column. They also stressed upon the ambiguity or non-existence of data on microplastics less than 300 μm and limitations in comparability of data, which inhibits the understanding of the microplastic's impact on the environment.

Nowadays, the possible chances of cascading of harmful effects of microplastics through the trophic layers of the ecosystem have been one of the main concerns of analysts. Numerous studies on calcification and ecotoxicity-based influences of microplastics on organisms have indicated that the ingestion of these plastics gravely affects the animals [12]. Some of the common issues include obstruction of gut, loss of lipid stores, elevated immune response, disorder in other normal physiological processes related to respiration, photosynthesis, reproduction, *etc*.

FPA-based Micro-FTIR (Focal Plane Array-based Micro-Foutier Transform Infrared) and Micro-Raman Spectroscopy are the analytical laboratory techniques used to measure the presence of microplastics [13]. Although durability and longevity are among the most valued merits of plastic products but these plastics when not managed well, often lead to contamination of the surrounding in both freshwater as well as marine environments. Also, products made of plastic degrade very slowly especially on exposure to ultraviolet radiation emitted by the sun and high temperatures. However, this degradation mainly causes the breakdown of the particles into very small sizes fragmented from macroscopic size to microscopic size and finally to indiscernible measurements called nanoplastics [14].

Microplastic presence in the flora and fauna largely affected the whole system in many ways and some are discussed below:

INFLUENCE OF MICROPLASTICS IN TERRESTRIAL ECOSYSTEMS

The ever-increasing usage of plastics as a packaging material and in various other forms has led to a massive accumulation of microplastics in our atmosphere. Microplastics have been detected in atmospheric fallout indicating their dispersion into and transportation *via* the air [15]. Research work assessing the impact of microplastics on land-dwelling creatures shows the occurrence of microplastics in livestock [16] and birds [17] and the ingested microplastics may discharge constituents which could be potential disrupters of the organism's endocrine system [18]. Analogous to microplastics in the aquatic environment, terrestrial microplastics can be relocated and biomagnified along the different levels of the food chain. High amount of microplastics in the soil has been reported to affect the biophysical properties of soil badly, along with its biota such as earthworms whose life processes like growth and reproduction drop because the microbes of their gut were disturbed by ingestion of these microplastics [15, 19].

Although many researchers have worked on the influences of microplastics on fauna, however, lesser work has been carried out on plants and agriculture. It was established that farmlands hold considerable microplastics since slush from sewage treatment and wastewater set up are frequently used as additives for soil in the agriculture [20]. In fact, wastewater as well as sewage treatment setups are substantial sources that contribute to environmental microplastics. The sludge in agricultural purposes often causes localized microplastic contamination which afterwards disseminates through transportation by either runoffs or soil and air biota [21, 22]. Till date there is limited statistical information available on the occurrence of microplastics in the land dwelling biota. However, experimental trials have revealed that the worms do take up these particles as a result of an

CHAPTER 4

Removal of Microplastic Contaminants from Aquatic Environment

Kuljit Kaur[1] and **Harpreet Kaur**[1,*]

[1] *Department of Chemistry, Lovely Professional University (LPU), Phagwara, 144411 Punjab, India*

Abstract: Microplastics (MPs) contamination has recently been recognized as a serious global concern for global food security and modern society's well-being due to its widespread presence in the aquatic and terrestrial environment. According to a growing number of reports, micro- and nanosized plastic components have been discovered in nearly every part of the world, from the bottom of the ocean to the mountain top. Microplastics have become prevalent in the environment due to the gradual disposal of plastic waste, a lack of conventional detection processes with particular removal techniques, and a slow disposal rate. By adsorbing various heavy metals, pathogens, and other chemical additives frequently utilised in the production of raw plastic, microplastics have been shown to work as potential vectors. At the tertiary level of the food chain, microplastics are consumed by marine organisms such as fish and crustaceans, and then by humans. This phenomenon is responsible for clogging digestive systems, disrupting digestion, and ultimately reducing the reproductive growth of entire living species. As a result of these repercussions, microplastics have become a growing concern as a new possible risk, demanding the management of microplastics in aquatic media. This review chapter gives a comprehensive overview of existing and newly developed technologies for detecting and removing microplastics from aquatic environments in order to minimise the ultimate possible impact on aquatic habitats.

Keywords: Activated carbon, Adsorption, Aqueous environment, Biochar, Immobilization, Microplastics, Microplastic characterization, Microplastic detection, Microplastic pollution, Microplastics remediation, Microplastics sources, Microplastic transport, Plastic waste, Primary microplastics, Porous media, Removal, Removal efficiency, Secondary microplastics, Toxicity, Water treatment.

* **Corresponding author Harpreet Kaur:** Department of Chemistry, Lovely Professional University (LPU), Phagwara, 144411 Punjab, India; E-mail: harpreet2.kaur@lpu.co.in

Rahul Singh and Neeta Raj Sharma (Eds.)

INTRODUCTION

Plastic pollution is a global issue that endangers both the environment and human health. Scientists and government officials have been paying close attention to the existence, distribution, and effects of plastic particles in the natural environment.

The global manufacturing of plastic has increased by 560 times in the last 60 years [1]. About half of it is used to make consumer products for one-time use, which are only used for a few moments before being discarded. Approximately 58% of plastic garbage accumulates in the natural environment, and is preserved in a solid state for the long period, whereas 18% of plastic garbage is recycled and 24% is burned [2]. The annual manufacturing of waste plastics was estimated to be greater than 348 million tons [3]. These plastics end up in the aquatic environment as a result of irresponsible handling, improper dumping, and aquaculture. When discarded plastics are subjected to sun radiation, temperature changes, waves and wind currents have physical consequences, while biological processes like fragmentation and thermal decomposition also take place [4]. Microplastics are plastic fragments having a diameter of less than 5 mm that have become the subject of research because of the danger they could cause to aquatic ecosystems and human health [5]. Microplastics are defined as plastic components, filaments, or beads with a diameter of 100 nm to <5 mm, while the particles having a diameter of less than 100 nm are called nanoplastics [6]. Based on their production pathways, they can be divided into primary and secondary microplastics [7]. Primary microplastics are commercially produced synthetically manufactured plastic pellets, beads, nurdles, fibers, and powders. Secondary microplastic particles are produced in the environment as a result of the weathering and decomposition of macroplastic and mesoplastic garbage [8, 9]. There are many ways that microplastics get into the environment, the most common of which are human activities in households, industries, and sewage systems [10]. They have the ability to adsorb heavy metals [11] and persistent organic pollutants [12] from the surrounding water environment. Organic contaminants such as polyaromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), perfluorinated alkyl substances (PFAS), polybrominated diethers (PBDs), and pharmaceuticals and personal care products [13], as well as trace metal contaminants such as Ag, Cd, Co, Cr, Cu, Hg, Ni, Pb, and Zn [14], can adhere to the surface of microplastics due to their hydrophobic nature. Hydrophobic organic contaminants (HOCs) have a high affinity for adsorption on non-polar surfaces including sediments and organic matter, however, they often choose surfaces made of plastic [15]. It has been outlined that if MPs and their micropollutants reach food webs *via* biota digestion, this could have consequences for ecosystems and human health [16] (Fig. **1**).

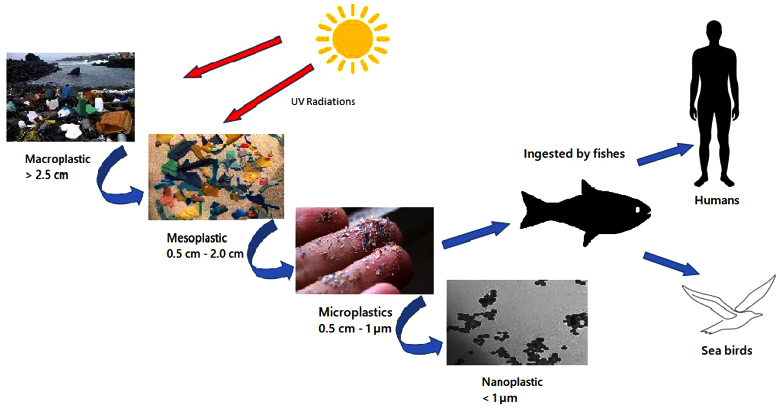

Fig. (1). Microplastics formation in the environment and their impact [17, 18, 19].

The recent global COVID-19 outbreak has increased demand for medical personal protection equipment (PPE), including single-use disposable face masks, medical face shields, and gloves, the bulk of these are composed of polymer materials [20, 21]. As a result of the pandemic, around 52 billion single-use disposable face masks were made in 2020 alone, with approximately 1.6 billion (3%) of them ending up in the oceans, where they will take 40-50 centuries to decompose. Tons of microplastics will be discharged into the oceans as a result of the natural breakdown of these masks, and these microplastics will most likely reach our food chain. Plastic waste has flooded the natural environment as a result of our excessive usage of plastic, and causing a number of environmental issues and threatening our health and survival [22, 23]. The sources, fates, occurrences, and dynamics of microplastics, as well as their interactions with biota and contaminants, have all expanded over the years. The increasing extent of microplastic waste in the environment is attracting global attention as the most serious concern addressing microplastic contamination, as well as the need for research to find long-term solutions to restrict its emissions and discharge into the environment.

In this chapter, various microplastic sources, entry paths of microplastics into the aqueous environment, and the toxicity and impacts of microplastic waste on living organisms are reviewed. We attempted to gather information on microplastic waste remediation approaches, with a focus on the removal of microplastics through adsorption and the application of biochar, a new adsorbent. In particular, biochar adsorption is examined as one of the most recent developments in the removal of microplastics.

CHAPTER 5

Status of Microplastic Pollution in Natural Water Bodies

Sadguru Prakash[1,*]

[1] *Department of Zoology, M.L.K. (P.G.) College, Balrampur, UP, India*

Abstract: The presence of microplastics in the environment has been declared as an emerging pollutant because the production of plastic is increasing tremendously throughout the world without proper management. Microplastics (MPs) are small plastic particles (size <5mm) released directly from the use of cosmetic products, or indirectly through the degradation of large plastic items under environmental conditions. Nowadays, it is estimated that annually between 4 and 14 million tonnes of plastic go into the seas and are hazardous to aquatic life. Fishes may ingest microplastics either directly or from the prey containing these particles. MPs were found between the stomach, gut, and intestine of the fish. These MPs accumulated in the fish body which causes serious health issues leading to mortality of the fish. MPs can cause various eco-toxicological effects on fish like behavioral change, cytotoxicity, neurotoxicity effects, liver stress, *etc*.

Keywords: Abundance, Bioaccumulation, Environment, Eco-toxicity, Freshwater, Fish, Hazard, Health-risk, Human, Interaction, Microplastic, Occurrence, Pollutant, Primary, Secondary, Toxicity.

INTRODUCTION

The word plastic originally referred to any substance that was easily molded and shaped (from the Greek adjective ‘plastikos’). Plastics were originally developed well before the twentieth century using natural materials such as insect secretion shellac, latex from tree sap, rubber, and celluloid. However, today when referring to plastics, we tend to mean synthetic long-chain organic polymers derived from the polymerization of monomers extracted from petroleum other products, including polyvinyl chloride (PVC), nylon, polyethylene (PE), polystyrene (PS), and poly-propylene (PP) [1].

* **Corresponding author Sadguru Prakash:** Department of Zoology, M.L.K.P.G. College, Balrampur, U.P. India; E-mail: sadguruprakash@gmail.com

Rahul Singh and Neeta Raj Sharma (Eds.)

Common plastic polymers include PP, PE, low-density polyethylene (LDPE), and polyacrylates [2]. They are lightweight, inexpensive, and durable materials, which can easily be sculptured into a variety of products that retrieve use in an extensive application. Plastics have attained a crucial status in modern life and are now ubiquitous [3]. Environmental conditions like thermooxidative process, photo oxidative method, ultrasonic processes, and microorganisms cause degradation of plastics into small fragments [4]. When plastic particles reach upto the size of <5mm, they are categorized as microplastics. The term “Microplastic” was formally introduced by Thompson [5].

Nowadays, microplastic particles have been ubiquitously detected in almost all aquatic habitats like deep oceans, river, lakes and sediments of the planet, in a broad range of shapes, polymers, sizes and concentrations in the environments of marine water, freshwater, agroecosystems, atmosphere, food and drinking-water, biota, and other remote locations [6]. Microplastics consist of carbon and hydrogen atoms bound together in polymer chains. Other chemicals, such as phthalates, polybrominated diphenyl ethers (PBDEs), and tetrabromobisphenol A (TBBPA), are typically also present in microplastics, and many of these chemical additives leach out of the plastics after entering the environment. Microplastics are actually a group of different toxins with varying hues and shapes [7]. Microplastics can contain two types of chemicals: (i) additives and polymeric raw materials (*e.g*., monomers or oligomers) originating from the plastics, and (ii) chemicals absorbed from the surrounding ambience. Lubricants and anti-adhesives are substances that facilitate the processing of plastic materials, improving their flow characteristics.

Microplastics found in the environment are a very heterogeneous group of particles differing in size, shape, chemical composition and specific density that originate from a variety of different sources. Based on their origin, they are also categorized into primary and secondary microplastics depending on whether the particles were originally manufactured to be that size (primary) or whether they have resulted from the breakdown of macroplastics (secondary). Thus primary microplastics are small sized plastic particles or fragments that are less than 5 mm in size before releasing directly into the environment whereas secondary microplastics are the fragmentation of larger plastic materials’ degradation under environmental conditions [8].

Examples of primary microplastics include microbeds found in personal care products, plastic pellets (or nurdles) used in industrial manufacturing, and plastic fibres used in synthetic textiles (*e.g*., nylon). Primary microplastics enter the environment directly through any of various channels for example, product use (*e.g*., personal care products being washed into wastewater systems from households), unintentional loss from spills during manufacturing or transport, or abrasion during washing (*e.g*., laundering of clothing made with synthetic textiles). Secondary microplastics form from the breakdown or degradation of larger plastics products (such as water or soda bottles and plastic bags) when they enter the environment; this typically happens when larger plastics undergo weathering, through exposure to, for example, wave action, wind abrasion, and ultraviolet radiation from sunlight. Microplastics are not biodegradable so when these enter once in the environment either in the form of primary or secondary microplastics. Microplastics also are a source of air pollution, occurring in dust and airborne fibrous particles. The health effects of microplastics inhalation are unknown.

Microplastic can be also categorized by their form, commonly in fibers, fragments, and spherical beads, as well as by their chemical composition, for example, polyethylene (PE), low-density PE (LDPE), PE terephthalate (PET), polyacrylates (PA), and so on [9]. MPs can be divided into many groups depending on the characteristics considered, describing a diversified class of materials that include a wide range of polymer types, particle sizes (ranging over 6 orders of magnitude), shapes (from spheres to fibers), and chemical formulations (thousands of different types), which are likely to be found in water [10]. Microplastic are of special concern science their bioaccumulation potential increases with decreasing size. MPs may be ingested by various organisms ranging from plankton and fish to birds and even mammals, and accumulate throughout the aquatic food web. Although plastics can absorb organic contaminants from the surrounding media. Since these compounds can transfer to organisms upon ingestion and serve as vectors for other organic pollutants and are, therefore, a source of exposure to organisms for these chemicals [11].

SOURCES OF MICROPLASTICS INTO THE ENVIRONMENT

The world's production of plastics (*i.e*. synthetic organic polymers) has strongly expanded during the last decades, from 1.7 million tons in 1950 to 299 million tons in 2013 [12]. Plastics have been found virtually in all environments ranging from the arctic to deserts to household dust. They are mainly introduced into the environment through ineffective waste management practices. Under environmental influences such as ultraviolet light and physical abrasion, the larger plastic particles degrade into macrocplastics (> 25 mm) which are degraded into mesoplastics (5-25mm) and then into microplastics (>5mm) in diameter [11]. Thus, microplastics, small pieces of plastic (<5mm), occur in the environment as a consequence of plastic pollution. The gradual reduction in size facilitates the transfer of plastic to a longer distance. By this, plastic can be considered a major emerging pollutant globally. These particles can transport other harmful

CHAPTER 6

Microplastic Pollution, A Threat to Human Health: A Case Study at Thoothukudi, South India

Sekar Selvam[1,*] and **Perumal Muthukumar**[1]

[1] *Department of Geology, V.O.Chidambaram College, Tuticorin-628008, Tamilnadu, India.*

Abstract: Microplastic pollution has become a serious problem that affects all marine and terrestrial environments worldwide. In this study, we investigated microplastics in the beach sediments and thus we collected 18 sediments from seven locations in Thoothukudi coastal area. Microplastics were separated and recognized using visual and micro-Fourier Transform Infrared spectroscopy (µFT-IR) studies. Microplastics' concentration ranges from high concentrations (up to 53 particles kg^{-1} d.w) in the dune areas to visibly lower ranges compared to beach sediments (up to 27 particles kg^{-1} d.w). The majority of microplastics identified in collected sediments were polyethylene (PE), polypropylene (PP), fiber(F), cellulose(CL) and nylon(NY) . The result of this study can provide valuable background information about microplastic pollution by using Atomic Force Microscopy (AFM) and the outcome of the results shows the presence of microplastics that pollute the marine environment in Thoothukudi coastal area and the human health risk in these areas.

Keywords: Aquatic ecosystem, Biota, Density extraction, Environment, Extraction, Electrostatic separation, FTIR, Filtration, Grab sampler, Identification, Microplastic, Magnetic extraction, Planktonic net, Pyr-GC-MS, QA/QC, Quantification, Raman spectroscopy, SEM, Sediment, Sample processing, Sampling, Terrestrial ecosystem.

INTRODUCTION

The amount of plastic production on a global scale increases every year. Since 1950, the world's plastic and polymer production has rapidly increased from 1.5 to 311 million tons in 2014 335 million tons in 2016 [1, 2]. Because of the increasing production of those polymers and their usage in low biodegradability, plastic contamination has turned into a serious environmental issue. A large quantity of plastics mainly end up in the marine environment and disturb the food chain of the marine ecosystem.

* **Corresponding author Sekar Selvam:** Department of Geology, V.O.Chidambaram College, Tuticorin-628008, Tamilnadu, India; E-mail: geoselvam10@gmail.com

Rahul Singh and Neeta Raj Sharma (Eds.)

It has been identified that nearly 4.8–12.7 million tons of plastic debris or plastic waste enter the marine environment and this amount will be increased rapidly by an order of magnitude before 2025. There are a few meanings of microplastics, for instance; Gregory (2009) characterized them as the barely visible particles that go through a 500 µm but are held by a 67 µm sieve [3], while Imhof *et al*. (2013) characterized particles less than 1 mm as microplastics [4]. These days, it is broadly acknowledged that plastic particles' size less than 5 mm are considered as microplastics (MSFD Technical Subgroup on Marine Litter 2013). Microplastics can enter the marine environment as primary or secondary pollution that contaminates the surrounding marine environment. Primary microplastics are polymers made in small scale, *e.g*., cosmetics [5] and medicine [6] parts or raw materials utilized for plastic production [7, 8]. Secondary microplastics are the results of physical (mechanical) degradation of greater plastic fragments [9 - 12]. In recent years, plastic pollution has received an increasing amount of interest from researchers, politicians, and the public. Microplastics (<5 mm) are a particular concern as they are suspected to accumulate in the environment and aquatic life.

Plastic is a generic term for man-made polymers that are most often prepared by polymerization of monomers from oil or gas. When not made from oil and gas, the polymer can be manufactured from coal, natural gasses, cellulose or latex from trees. The molecular backbone of a plastic polymer is typically composed of hydrocarbons and other naturally occurring compounds. Other chemicals, additives, are also added to the polymer to provide desirable properties, such as plasticizers that are added to improve the malleability of certain polymers. We now live in "a plastic world" where almost everything surrounding us is made of plastic, and it is hard to imagine a world free of this material. Plastic production has increased dramatically worldwide over the last 60 years, and is still increasing, with the current production of around 300 million tons yearly.

MICROPLASTICS IN MARINE ENVIRONMENT

Microplastics can pollute the marine environment in two ways: as primary pollution and as secondary contamination. Primary microplastics are polymers that are used in microscale items in everyday life, such as cosmetic and medical components, or as raw materials in the creation of plastics. Physical (mechanical) breakdown and bigger plastic particles produce secondary microplastics. Microplastics have been shown to damage creatures at all trophic levels in the marine environment, including worms, fish, sea turtles, birds, and mammals. Microplastics are mistaken for food by many creatures, and they selectively feed on them instead of food. The debris in the stomach might restrict appropriate food intake generated by a sensation of fullness and lessen feelings of hunger, so reducing the desire to eat. As a result, the pace of growth might be reduced and reproductive capacity and the ability to avoid predators. Ingested plastic can cause fast fatality if the gastrointestinal system is entirely clogged or seriously injured by abrasions and ulcers. At concentration levels, plastic waste in the marine environment comprises a variety of hydrophobic contaminants and trace metals. Some of these chemicals are added to plastics during the manufacturing process, while others are absorbed from the seawater. Organic pollutants can interfere with normal hormone functioning in some marine animals, causing mutations and cancer. Hydrophobic organic pollutants have been demonstrated to have a stronger affinity for polymers such as polyethylene, polypropylene, and polyvinyl chloride than for natural sediments. The micro-scale reduction of plastic litter apparently improves their absorption capabilities and accelerates the passage of hazardous chemicals from plastics into organisms. Microplastics have been found all over the world, not just in densely populated areas, but also in remote areas and deposition zones. Microplastics' sources in the maritime environment have not been well investigated. Harbours and shipyards, fisheries, waste water treatment facilities, coastal tourism, urban runoff, and rivers are all likely sources of their contributions. The fate of these organisms in beach and bottom sediments is currently unknown. Although it has long been recognised that sediments may acquire microplastics, no obvious association between microplastic concentration and sediment grain size has been discovered, as has been the case with organic matter and some other pollutants [13]. Aggregation with organic materials, on the other hand, may play a key role in microplastic transport. Long water exchange also encourages the building of contaminants in the area. The authors claim that this is the first research to evaluate the shape, concentration, and fate of microplastics in bottom and beach sediments. The primary sources of microplastics were also identified with their effect on human health.

The world's seas and oceans are subjected to different kinds of threats, of which the accumulation of anthropogenic debris is a major and worldwide problem that has been an environmental concern for decades. Despite increased worldwide attention, the accumulation of these materials in the environment is seen as an issue due to rising global plastic manufacturing (280 million tonnes in 2011) and continued poor plastic waste disposal. It has been established in the previous decade that big plastic items in the marine environment break up into smaller particles with dimensions as thin as a safe micrometre, known as microplastics. Moreover, additional sources of microplastics have been identified. Microplastic particles present in cosmetics and those fibres from fabrics such as polyester and polyamide present in wastewater used domestically are not retained during the treatment of sewage and can thus enter the coastal environment. Many authors have defined microplastics as particles smaller than 5 mm, while others have set

CHAPTER 7

Microplastic as a Multiple Stressor

Savita Bhardwaj[1], **Dhriti Sharma**[1], **Tunisha Verma**[1] and **Dhriti Kapoor**[1,*]

[1] *Department of Botany, School of Bioengineering and Biosciences, Lovely Professional University, Phagwara (Punjab), India*

Abstract: The presence of microplastics (MPs) throughout the world causes a serious threat to the functionality and vigor of the ecosystem, which is present in almost all habitats, such as in aquatic, atmospheric and terrestrial habitats, and is also found in human consumables. Recently it has been found that MPs have entered the human body through the food chain from terrestrial agriculture. Migration and retention of MPs in the soil are controlled by the interaction between MPs and various environmental factors. There is an immense need in real-world environments to understand the migration properties and key mechanisms of MPs. Various organisms such as plants, animals, different microorganisms present in the soil, *etc*. are impacted by the presence of toxic MPs in the environment. Therefore, to ensure food safety and sustainable agriculture, MPs should be treated as a future threat and attention should be given to understand the mechanisms of transport and ecotoxicological effects of contaminants released from MPs. The aim of the present chapter is to emphasize the impact of MPs on various organisms present in the ecosystem and their interaction with other contaminants.

Keywords: Antioxidative enzymes, Contaminants, Ecosystem, Embryonic development, Fecundity, Food chain, Hazard, Human health, Microbes, Mortality, Microplastics, Multiple stressors, Nanoplastics, Non-degradation, Oxidative stress, Plant growth, Reactive oxygen species, Seed germination, Stress responsive genes, Toxicity.

INTRODUCTION

Plastic has become a ubiquitous material nowadays owing to its properties such as low weight, durability, rust resistance along with low electrical and thermal conductivity [1 - 3]. Though its mass production, mismanaged usage, and non-degradation coupled with inappropriate waste disposal, have made it a serious ecological hazard whereby it causes acute damage to the environment [4, 5].

* **Corresponding author Dhriti Kapoor:** Department of Botany, School of Bioengineering and Biosciences, Lovely Professional University, Phagwara (Punjab), India; E-mail: dhriti405@gmail.com

Rahul Singh and Neeta Raj Sharma (Eds.)

Further, the widespread applications of plastics have resulted in releasing them on a large scale into aquatic and terrestrial environments where they will persist for centuries owing to the difficulty in their natural degradation. Plastic is being extensively deposited in the world's oceans as 70–80% of plastics are transported by rivers [6]. Natural ecosystems contain plastic debris of almost every shape and size and until recently, the maximum damage is caused by large-sized plastic articles. For example, several problems have been reported by different studies like mortality in sea turtles [7] and entangled seabirds following ingestion [8, 9].

However, microplastics appeared as a facet of great public concern in current times, and are defined as materials having dimension with an upper limit of <1 mm, as per the recommendations of Hartmann *et al*. [10]; whereas the size of plastic debris varies from microscopic particles to pieces to meters in dimensions. MPs exist contrary to the large-sized plastic refuse in the ecosystem as these are comparatively minute in size being almost invisible and cannot be eliminated from territories for reuse. MPs are considered ubiquitous anthropogenic contaminants in the ecosystem as they pose serious health effects and originate from different sources in the ecosystem.

Categorization of microplastics has been done into primary and secondary forms by taking into account the nature of their origin. Primary MPs are those which are produced at a tiny size and are commonly present in cosmetic products, drug materials and textiles [11, 12]. While UV-radiation and mechanical abrasion triggered breakage of larger plastic debris to produce fragmentation products are known as secondary MPs [13]. Secondary MPs are mainly found in industrial raw substances, domestic products, fishing nets, films, and other waste plastic remains [14]. MPs are not only an aesthetic issue, but also cause several other serious problems and impact various organisms due to their extended lifecycle, widespread presence all around the habitats, and minute size.

Furthermore, noxious chemicals which are released by the MPs, are utilized as plastic additives during the manufacturing and accumulate organic pollutants in them from the adjacent surroundings. Upon gaining entry into the food chains, these accumulated contaminants in MPs are then transferred to higher trophic levels from the environment [15]. Additionally, these MPs accumulated contaminants also cause acute toxicity in agronomic products and ultimately pose serious problems to human health [16].

MICROPLASTIC AS STRESSOR

Aquatic Environment

Different organisms experience different exposure to MPs such as organisms present at the bottom of the water surface encounter denser MPs like that of PET (polyethylene terephthalate) and PVC (polyvinyl chloride), while organisms present at surface waters come across those MPs which are less dense than seawater, for instance, PS (polystyrene), PP (polypropylene), and PE (polyethylene) [17]. The effect of MP fibers was studied in terms of the physiological and reproductive outcomes in pacific mole crabs *(Emerita analoga*) and mortality, fecundity, and embryonic developmental rates of crabs kept under control and microfiber-exposed conditions were compared. It was observed that the exposure to MPs increases with the increase in plastic usage and their addition to aquatic streams. The mortality rate was increased and embryonic development was also affected by an increase in the number of embryonic stages by MP microfibers [18].

MPs are also ingested, accumulated and transported into the hemolymph of Sydney rock oysters (*Saccostrea glomerata*) through microfold cells [19]. Microalgae, which are the primary producers of the aquatic system get impacted by MPs through a decline in their development and photosynthesis [20]. Alterations in the morphological parameters, a decline in the content of chlorophyll, and over-accumulation of ROS, were observed in microalgae by MPs [21]. The liver of fishes gets damaged*via* their exposure to MPs causing high lipid accumulation, inflammation, and also by a disturbance in lipid and energy metabolism [22]. Expression of inflammation-related and oxidative stress genes was increased, while a reduction in swimming competence and predacity along with the ability to locate the food *i.e*. population vigor; was also observed in young fishes [23]. In Zebra fishes, MPs exposure caused gut impairment and changes in the gut metabolome and microbiome [24]. Both direct and indirect toxicities can be imposed by MPs. Moreover, assessment of the interactive toxicity potential of MPs is also necessary as they can interact with other contaminants in the ecosystem [25].

Survival of lugworms (*Arenicola marina*) was found to be decreased due to the inhibition of their feeding activity and energy reserves by their exposure to MPs [26, 27]. Unusual swimming behavior in the goby (*Pomatoschistus microps*) was observed, whereas in Asian green mussel *Perna viridis*, aspects like the rate of respiration, production of byssus and clearance of food were decreased *via* their exposure to MPs [28, 29] which ultimately famish them to death in both the organisms. MPs ingestion in oysters markedly caused inhibition of the process of

CHAPTER 8

Bioplastic as an Alternative to Microplastic

Rohan Samir Kumar Sachan[1], **Manpreet Kaur Somal**[2], **Ritu Bala**[1], **Khushboo**[1], **Mukesh Kumar**[1], **Inderpal Devgon**[1] and **Arun Karnwal**[1,*]

[1] *Department of Microbiology, School of Bioengineering and Biosciences, Lovely Professional University, Phagwara-144411, Punjab, India*

[2] *Department of Biotechnology, School of Bioengineering and Biosciences, Lovely Professional University, Phagwara-144411, Punjab, India*

Abstract: Microplastics pose an imminent risk to the marine environment, biota, and ecosystem. Their consumption threatens organisms because of the material's ability to absorb and concentrate environmental contaminants in oceans and then transfer them through food chains. Microplastic may harm soil biota, such as earthworms, and can alter soil biophysical parameters, such as soil bulk density, aggregation, and water-holding capacity. To find alternatives to microplastics, scientists have developed biodegradable plastics that can be discarded in the environment and broken down quickly by the enzymatic activity of micro-organisms. Bioplastics are made from biological or renewable components. The bioplastic produced from potato peels, corn, sugarcane, wheat, rice, banana peels, and other natural materials is eco-friendly and biodegradable. Bioplastic is also known as Low-carbon plastic. The use of low-carbon plastic aids in the regulation of global temperature rise. It is used to make toys, home interiors, shopping bags, bottles, labels, trash bags, and packaging materials. It has wide applications for bone nails and tissue scaffolds in the medical industry. Its development also faces other obstacles, including price difficulties, technical improvements, and waste collection and treatment. Synthesis and characterization methods will help overcome these obstacles. The present chapter will focus on bioplastic and its types, the synthesis of bioplastic, the difference between microplastic and bioplastic, and bioplastic as an alternative approach.

Keywords: Additives, Anthropogenic contaminants, Biocompatible, Biodegradable, Bioplastic, Biopolymer, Economic feasibility, Human health, Microplastic human, Microplastic ingestion, Multi-stress, Nano-plastics, PHA-based composites, PHA-producing bacteria, Plastic pollution, Plastic, Polyhydroxyalkonate, Polyhydroxy butyrate, Polystyrene microplastic, Waste feedstocks.

* **Corresponding author Arun Karnwal:** Department of Microbiology, School of Bioengineering and Biosciences, Lovely Professional University, Phagwara-144411, Punjab, India; E-mail: arunkarnwal@gmail.com

Rahul Singh and Neeta Raj Sharma (Eds.)

INTRODUCTION

The monomers' polymerization extracted from the hydrocarbons creates synthetic organic polymers in nature. In 2016, the annual production of plastics reached 335 million worldwide [1]. The pollutants of plastics enter the ocean in many ways and constantly gather in the marine environment affecting marine life. As plastics are a prevalent and persistent pollutant to this date, they cause many impacts such as the effect on reproduction, ingestion, and non-native species translocation [2]. Land-based sources of plastics such as industries, riverine, urbanization, and tourism are more than sea-based plastic sources [3]. It indicates that more significant coastal site produces considerable plastic pollution [4]. The primary microplastics are microscopic; examples are resin pellets preproduction, blasting, toothpaste, microbeads in cosmetics, and media in drug delivery [5].

The degradation of larger plastics due to mechanical fragmentation and biological degradation leads to the formation of secondary microplastics [6]. The secondary microplastics include fabric from microfibers, fragments of plastic, and tire wire debris [7]. Microplastics are primarily available in marine organisms due to their spatial distribution and small size. For instance, microplastic found in shellfish, marine food, canned food, and mineral drinking water is stated to ingest by humans [8, 9]. From the coast of Rapa Nui, 80% of the *Decapterus muroadsi* sample has ingested microplastics. It has also been reported that 26 different species of fish from the various habitats of the red seacoast of Saudi Arabia also consumed the microplastic.

Renewable resources produce bioplastics as an alternative to microplastics or petrochemical-derived plastics [10]. Bioplastic is generally derived from natural resources. Bioplastic is categorized into two parts; biodegradable and non – biodegradable. Biodegradable plastic includes PLA (polylactic acid), PHA (polyhydroxyalkanoates), starch, and cellulose. Some plastics, including oil-based and biodegradable biobased plastic, can be incinerated as they are not entirely recycled and cause contamination in the recycling process. The non-biodegradable bioplastic includes bio-polyethylene terephthalate. The optically active PHAs are biodegradable polymers synthesized by bacteria during nutrient deprivation such as nitrogen, phosphate, and excess carbon. The microbial cell lysis and the microbial fermentation process are used for the PHAs production as they are biocompatible, biodegradable, and non-toxic polyesters. The diversity in their monomeric compositions is due to the variations in their physical properties as they carry wide applications [11].

HARMFUL EFFECT OF MICRO-PLASTIC

Today, micro-plastic is a top problem for the whole world; bio-plastic consumption shows many adverse effects on human and marine life. According to the Central Pollution Control Board, New Delhi, in 2014, 5.6 million tons of plastic were consumed in India, whose disposal is significant. Removal of industrial toxins and plastic waste in water bodies leads to an increase in the micro-plastic consumed by sea fish and seafood transfers that bioplastic to humans, which can act as a vector for different industrial toxins to enter the human body [12].

These insoluble synthetic solid particles cause pollution and become a high risk to marine life and humans, exposing micro-plastics to organisms [13].

Microplastics' physical and chemical effects are harming human and marine life see Fig. (**1**). In a 2016 UN report, more than 800 animal species engulfed or consumed micro-plastic. Among them, 220 species ingested micro-plastics get bloated in the organism's tract. As a part of the food chain, consumers may have consumed micro-plastic showing adverse effects like hemocyte aggregation and reduced respiratory function. It also activates an immune response in blue mussels and forms granulomas hepatic stress. In Japanese medaka, translocation of micro-plastic to the lymphatic system shows adverse effects on the immune system and cells. Even low dose consumption of chemicals applied to microplastic affects the biological system posing a risk to young humans and animals [14]. Adverse effects like breast cancer, defects in calcium metabolisms, cell apoptosis, female metal-estrogen, cell genotoxicity, porous bones (Osteoporoses), and cell conversion to cancerous cells are seen in humans [13, 15].

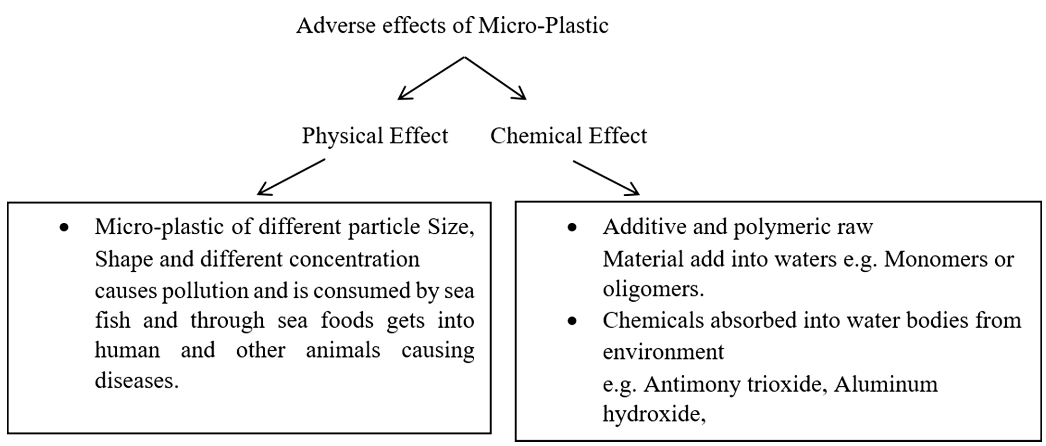

Fig. (1). Flow chart: Different effects of Micro-plastic.

CHAPTER 9

Challenges to the Analysis of Microplastic Pollution from the Environment

Nafiaah Naqash[1] and **Rahul Singh**[1,*]

[1] School of Bioengineering and Biosciences, Lovely Professional University, Phagwara-144411, Punjab, India

Abstract: A growing interest in microplastic pollution in the environment demands simple, inexpensive, comparable, and robust methods for microplastic (MP) analysis. A wide range of methodologies for sampling, sample preparation, and MP analysis are in use. This chapter discusses the most common detection methods, as well as sampling strategies and sample preparation methods along with a special emphasis on challenges. The spectroscopic methods require time-consuming sample preparation and measurement durations, whereas thermo-analytical methods are faster but lack the ability to determine sample size distribution. Many articles concerning the quality and quantity of MPs in various matrices have been published. However, drawbacks and limitations in MP analyses are frequently overlooked or ignored. As a result, depending on the defined analytical question, the majority of the described methods are applicable. As a result, this chapter summarizes current sampling, sample preparation, and analysis methods, discusses limitations, and outlines the complexities associated with MP loss or contamination during sampling and laboratory testing.

Keywords: Characterization, Digestion, Detection, Density separation, Extraction, FTIR, Identification, Infrared spectroscopy, Limitations, Microplastic, Occurrence, Processing, Purification, Pyr-GC-MS, Quality, Quantification, Raman, SEM, Spectrometry, Sampling.

INTRODUCTION

Microplastics are ubiquitously found in diverse environmental systems, including marine waters, sediments, freshwater, and terrestrial ecosystems, including biota. Microplastics are a threat to the environment, and their presence, especially in water, has a negative influence on ecology and human health. They are discharged into the environment through a variety of sources, including ordinary plastic products, plastic degradation, industries, and wastewater treatment plants [1].

* **Corresponding author Rahul Singh:** School of Bioengineering and Biosciences, Lovely Professional University, Phagwara-144411, Punjab, India Email: rahulsingh.mlkzoology@gmail.com

Rahul Singh and Neeta Raj Sharma (Eds.)

Once they reach water, aquatic biota feeds on these toxins, and microplastic enters the food chain, posing serious health risks.

The analysis of microplastics from the environment is more challenging than larger plastic particles. Microplastics are pervasive, slow-degrading pollutants with characteristics such as durability, high stability, high fragmentation potential, and the ability to adsorb additional contaminants [2, 3]. Organic pollutants such as heavy metals, polyamide, polyester, polymerizing vinyl chloride, and acrylics have been found adhered to microplastics in previous investigations. Furthermore, it releases toxic compounds that are detrimental to humans as a result of trophic transfer from marine, freshwater, and terrestrial organisms. Although it is widely acknowledged that microplastics pose a threat to the environment, the numerous consequences of microplastics to the ecosystem have not been thoroughly investigated. In that case, it is critically important to enhance research techniques for analyzing microplastics from the environment. Microplastics should be analyzed as an emerging worldwide contaminant in order to assess potential impacts on the environment and humans [4].

Microplastics are a major challenge on their own, however, the first challenge to eliminate them involves the complete identification of their type, form, and morphology [4]. Plastic does not have a single molecular structure but is made up of a number of polymeric components of various sizes, shapes, and compositions with diverse additives. Further, from the methodological point of view, visual identification is inexpensive and relatively simple. However, this provides only a small portion of the total picture of microplastic abundance in the environment. More advanced techniques are necessary and were developed in recent decades to lower the limit of detection for microplastics in terms of particle size, false identification of particles as plastics, and, specifically to process larger sampling amounts in less duration for monitoring. Previous studies have considered bulk sample volume, sieving, filter pore size, density separation, and organic digestion for microplastic sampling. However, the use of novel methods, such as the enhancement of visual identification by staining dyes and the generalized use of chemical characterization, will improve sampling procedures for microplastics. Currently, the majority of research is focused on identifying and quantifying techniques of microplastics. The procedures include rapid screening techniques based on visual identification to a complex mix of analytical techniques that provide information on polymer type, particle number or mass, and particle size, which are extremely expensive and time-consuming. Though, the lack of standardized methods and protocols among researchers, and many approaches now in use may underestimate or overstate microplastic contamination, ensuing in contradictory data [5]. Therefore, it is mandatory to create standardized methodologies, such as sampling and identification methods for microplastics, to collect comparable monitoring data. In this chapter, we focused on the challenges experienced during primary methodologies and strategies for sampling, separating, identifying, and quantifying microplastics in the environment. The analytical procedures involved can provide basic descriptions of pollution levels, shifting patterns in microplastic concentrations, and the risk of organism exposure. To ensure the uniformity of microplastic data in the environment, the effectiveness and limitations of primary procedures and techniques for sampling, separating, detecting, and analyzing microplastics in the environment must be adopted as soon as possible.

ENVIRONMENTAL SAMPLING AND CHALLENGES

Microplastic has already been detected in freshwater, benthic sediment, soil, atmospheres, seas, and beach sand, as well as in far-flung locations such as the arctic regions and the Tibet Plateau. Microplastic can also be taken up by a variety of aquatic and terrestrial flora and fauna. As a result, microplastics may have a wide range of effects on the earth's ecosystem, and thus need to be addressed. Analyzing microplastics in the environment can offer fundamental information on pollution levels, changing patterns in microplastic concentrations, and the risk of organism exposure. The initial method of identifying and measuring microplastic contamination is to gather microplastic samples from major collecting areas including water, sediment, soil, and biota. The sampling procedures are obviously different, which ultimately alters the microplastic concentration.

Marine and Freshwater Sampling

To access microplastic contamination of marine and freshwater systems, large quantities of water are filtered through nets. Both freshwater and marine systems have similar sampling procedures, therefore, allowing for standardization of sampling methods in the future. However, different densities of 1.00 g/cm^3 and 1.03 g/cm^3 of freshwater and marine waters, respectively, could contribute to varying distributions of microplastics in the water column of each system [6]. Trawling is the most frequent type of water sampling, wherein Neuston and Manta trawl nets have been utilized most commonly. Furthermore, to estimate the sample volume, nets should be fitted with flow meters which allow the results to be expressed in m^3. Microplastic pollution in marine water across the Tropical Eastern Pacific and Galapagos was sampled using plankton nets with a 60 cm diameter, 3 m length, and 150 µm and 500 µm pore size. To avoid any oil or litter contamination from the main vessel, both nets were deployed simultaneously at a distance of 30 meters from the ship's stern [7]. Although, the Manta net allows sampling of large quantities of water; however, Plankton nets have also been

CHAPTER 10

Distribution of Microplastics in Man-made Water Bodies

Suraya Partap Singh[1,*] and **Reetika Rani**[2]

[1] *Department of Zoology, Government Degree College, Boys, Kathua, Jammu & Kashmir, India*

[2] *Department of Zoology, School of Bioengineering and Biosciences, Lovely Professional University, Phagwara, Punjab, India*

Abstract: Plastic is one of the most commonly produced and used materials in the world due to its great features. It has also become the most prevalent type of debris found in our oceans, lakes, wetlands, and other lentic systems. Plastic (from the Greek "plastikos", meaning mouldable) is made of synthetic organic polymers. Anthropogenic activity has resulted in the deposition of a complex combination of materials in different water bodies, which may include synthetic polymers (plastics) which are degraded into smaller fragments which will be in the size of <5 mm; these are termed microplastics. Microplastic pollution is one of the main matters of concern nowadays, specifically due to the increasing anthropogenic activities in and around the different water bodies which lead to ubiquitous distribution of microplastics in water systems. It is a gleaming topic among the environmentalists of the world. The environmental release of MPs will occur from a wide variety of sources, including emissions from wastewater treatment plants, cosmetics, toothpaste, *etc*. and from the degradation of larger plastic debris. In recent years, interest in the effects of microplastics (MPs) has shifted towards freshwater ecosystems and in this chapter, we provide an overview of the issues of microplastic pollution that are concerned with manmade water bodies which can be inland as well as coastal environments as well as the sources of contamination of water bodies with microplastics, their influence and a conclusion.

Keywords: Aquatic, Coastal, Contamination, Cosmetics, Debris, Degradation, Environment, Items, Inland, Lake, Lentic, Manmade, Microplastics, Monomers, Ocean, Plastic, Pollution, Treatment, Water bodies, Wastewater.

INTRODUCTION

Waterbodies are defined as systems that have an accumulation of water on the surface of the planet Earth. The study of freshwater inland waters including lakes ponds, rivers, springs, streams, and wetlands is termed Limnology, and Oceano-

[*] **Corresponding author Suraya Partap Singh:** Department of Zoology, Government Degree College, Boys, Kathua, Jammu & Kashmir, India; E-mail: suraya9@gmail.com

Rahul Singh and Neeta Raj Sharma (Eds.)

graphy deals with the study of ocean water, it covers a wide range of topics, including marine life and ecosystems, ocean circulation, plate tectonics and the geology of the seafloor, and the chemical and physical properties of the ocean. Waterbodies are known by a plethora of different names in English: rivers, streams, ponds, bays, gulfs, seas, *etc*.

Generally, water bodies are naturally occurring bodies but with the modifications of living standards and increasing mental capability, human beings started building artificial water bodies for certain purposes. Such water bodies which are maintained by anthropogenic activities are termed Man-made water bodies. It started with the building of small ponds in villages for certain purposes like passing the dry spell to small tanks for storing water and reaching up to huge reservoirs which can be large-sized dams, reservoirs, large-sized tanks, abandoned quarries, *etc*. There are a number of artificial water bodies. The US accounts for approximately 20% of the standing water area under artificial water bodies and their impact on hydrology, sedimentology, geochemistry, and ecology is apparently large in proportion to their area [1]. In India, there are maximum inland water bodies as compared to the coastal type of water bodies. According to the Ministry of Jal Shakti of India, the Inland water resources of the country are classified as rivers and canals, and reservoirs, which include tanks and ponds. The brackish water lakes are also present in India. Except rivers and canals, total water bodies cover about 7 million hectares of the geographical area of India. Even the country experiences serious water scarcity problems due to the unequal spatial distribution of water resources and high population density. To cope up with this, India has constructed a number of wetlands which are shown in Fig. (**1**) where the wastewater is treated for reuse. The source and quality of the wastewater are also important aspects that are being observed properly while maintaining artificial wetlands in developing countries. The waste-water containing industrial wastes, domestic and organic wastes is largely used for constructing such wetlands [2]. The main aim of constructing these wetlands is to do advanced treatment of waste-water so that better quality water can be used for different purposes. The ecosystem of the artificial water bodies brings froth various advantages to residents of that area which are enlisted as a source of nutrition, hydration, and clean water for the use of human beings even for irrigation and other agricultural perspectives [3].

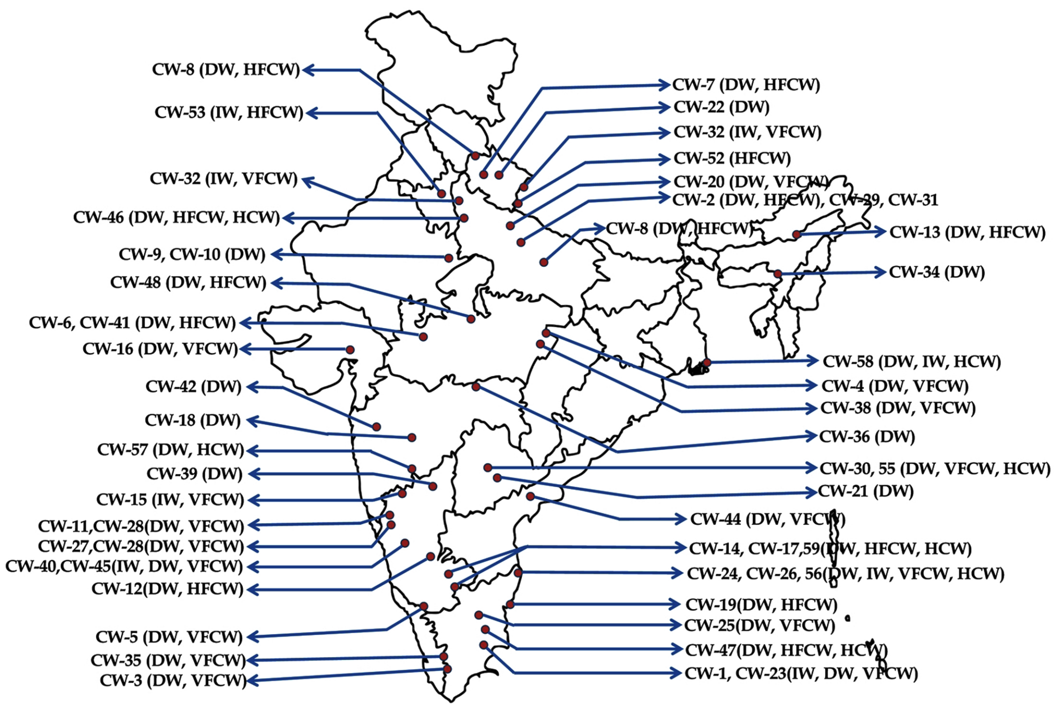

Fig. (1). The site distribution of constructed wetlands (CWs) in India. (Where: Constructed wetland number-1 (CW-1)), HFCW: Horizontal flow constructed wetland, VFCW: Vertical flow constructed wetland, HCW: Hybrid constructed wetland, DW: Domestic wastewater, IW: Industrial wastewater [3].

Plastics are generally synthetic or semi-synthetic materials manufactured by using polymers as main components. The word plastics was coined by Leo Hendrick Baekeland as he invented the fully synthetic plastic that is Bakelite. He is even termed as 'Father of the Plastic Industry' [4]. The word *plastic* derives from the Greek word (*plastikos*) meaning capable of being moldable and is made of synthetic organic polymers, which are usually produced through the polymerization of monomers derived from oil, gas, or coal [5]. The commercial production of plastic started in the 1940s and 1950s [6]. Plastics have brought great convenience to our daily lives but not without problems. The inappropriate disposal of wasted plastics has caused serious environmental problems. Over the past decade, microplastic debris are found in both marine and freshwater systems and it became an emerging issue [7]. All types of plastics are responsible for the degradation of the environment and have varied implications on different ecosystems; however, recently microplastics (MPs) have gained much interest in the scientific community. When plastic particles reach up to a size of <5mm, they are categorized as Microplastics [8]. 0.33 mm was defined as a lower limit for the size of microplastics based on the common mesh size of the Neuston nets which

SUBJECT INDEX

A

B

C

Rahul Singh and Neeta Raj Sharma (Eds.)

D

E

F

G

H

I

J

L

M

N

O

P

Q

R

S

T

W

Rahul Singh

Prof. Rahul Singh is a highly accomplished professor in the Department of Zoology at Lovely Professional University in Phagwara, Punjab, India. With a specialization in fish and fisheries, he has established himself as an expert in his field. He holds a Ph.D. in zoology from Dr. Ram Manohar Lohia Avadh University in Faizabad, Uttar Pradesh, India. His research interests include fish probiotics, microplastic contamination and toxicity, and aquaponics. His work in these fields has earned him numerous accolades and awards. Notably, he received the Research Appreciation Award from Lovely Professional University and was appointed as a member of the "Pradhan Mantri Matsya Sampda Yojna (PMMSY)" for District Kapurthala by the Department of Fisheries, Ministry of Fisheries, Animal Husbandry, and Dairying, Government of India. Prof. Singh has made significant contributions to the field of fish and fisheries through his extensive research and his dedication and commitment to environmental sustainability has made him a prominent figure in the academic community. He has authored several research papers.