Jeopardy of Indian Waters: A Review

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Received September 03, 2020; Revised October 05, 2020; Accepted October 14, 2020

Abstract Microplastic pollution is a new emerging problem to our generation, with lack of proper disposal and
tones of production. Every year tones of plastic is disposed in the water bodies and which gets weathered and results
in the production of microplastics, which when ingested by aquatic organisms leads to their mortality and many
serious issues. The microplastics are good adsorbents and absorb all the chemical and metals in the water causing
mortality in fishes. They also act as pathogen carriers and lead to the water born diseases. Our review study finds
that there is a need to evaluate the effects on the fresh water organisms as the literature on fresh water is scarce.

Keywords: Microplastic pollution, micro plastics, India, first report, lakes, bioaccumulation

Cite This Article: Juhi Firdous, Yatindra Kumar Mathur, Mubashir Jeeelani, and Seema Azmat, “Jeopardy of
Indian Waters: A Review.” Applied Ecology and Environmental Sciences, vol. 8, no. 6 (2020): 472-477.
doi: 10.12691/aees-8-6-20.

1. Introduction

Microplastics are a hot topic for the human civilization, as what is it and how is it introduced to the environment.
Many attempts have been made by various researchers to study the presence and impact of micro plastics on life
aquatic organisms and environment, but somehow either one way or the other the fate of micro plastics in the end is
unknown which makes its a burning topic of debate itself. Our modern age era is the age of plastics with much
pressure from humans on the environment and yet makes the fate of these micro plastics less studied [1]. The first
report on marine micro plastics was reported in 1970’s, small plastic pellets were found in nuston nets in Sargasso Sea [2]. Various studies carried out suggest that these micro plastics are widespread in water systems including remote lakes and rivers [3,4]. Microplastics are basically hydrocarbons which are bound to each other by
polymer chains; they can be classified as primary and secondary microplastics. Primary microplastics are plastic
fragments which are usually 5.0 mm in size when they cross the threshold environment they include microfibers,
microbeads and plastic pellets [3]. Secondary microplastics are formed from larger plastic when they enter the
environment and get weathered; they include plastic bottles, fishing nets, plastic wrappers and bags [5,6]. It was
found that urban lakes had higher concentration of micro plastics [7], however very less data is available on micro
plastic pollution in fresh water ecosystems which makes it difficult to analyze the widespread contamination
of micro plastics. The source of micro plastics can be point and non-point sources which include sewage
treatment plants and manufacturing units, manufacturing consumer plastics [8]. The main sources of micro plastics
are the larger plastics which upon disintegration by UV radiations break into smaller plastics [1]. Micro plastics in
marine ecosystems have been found all over the world in surface waters as well as sediments and various organisms
were investigated for the presence of micro plastics [9] and micro plastics were found in the guts of many organ
isms at every tropic level from zooplanktons to vertebrates [4,10]. It is suggested that accumulation of MP’s in
organisms can cause physiological dysfunction in animals which in turn can prove fatal to human population which
depend on these organisms for their protein sources [11,12]. Micro plastics act as reactive surfaces for many
substances like heavy metals, pesticides and many xenobiotics [13,14]. They are very prone to microbial
colonization and act as their niches and form a base for microbial life. Micro plastics can be transported over long
distances and act as vectors for spread of pathogenic bacteria [15,16]. Micro plastic pollution in India was
unnoticed till 2013; the first study carried out by H.B. Jayasiri et al., [17] was a study regarding the plastic
accumulation on urban beaches of Mumbai. It was found that Juhu beach had the highest quantity of plastics as
compared to other beaches in Mumbai, mostly in the month of November when the tourist activity is on its
peak. It was found that the mega plastics dominated the beach samples; the origin of the plastics was showed to be
primarily of land origin which when carried by winds reach the waters. The same author carried out a study in
2015 with his co-authors on the plastic pellets from Mumbai beaches and concluded that the plastic pellets are
traps for various cycloidiene compounds and many pesticides which further add a nail to the coffin of Indian
In 2016, S. Veerasingham et al. [18], carried out a study on beaches of Goa and collected samples from two beaches for 3 months and concluded that the source of primary micro plastics were the ship leakages or other sources in sea which when carried by the hydrodynamics reach the beaches. In January and June plastics deposition was found in high quantity because of pre-monsoon and post-monsoon as compared to other months, the authors also concluded that these micro plastics also act as accumulating base for other substances and can cause harmful effects in living organisms. They plastic samples collected in the month of January were found to be more weathered than the June ones, which mean they could be weathered on land before deposition in beach waters. The same author also carried out a study on the impact of 2015 floods on distribution and occurrence of micro plastic pellets along Chennai coast in India. The study showed that the floods in Chennai had a large impact on micro plastic pellet distribution and deposition. The abundance of micro plastic pellets post-floods in Chennai were found to be three fold of the abundance pre-floods, wind and ocean currents were responsible for transportation and deposition of micro plastic pellets in Chennai cost. The study also showed the adhesion of black substances to the surfaces of these micro plastic pellets which show that the surface of these MPP’s act as accumulating surface for all the substances. M.Mugilarasan et al., [19], carried out a study on micro plastic pellets in Tinnakkara Island, quantity of micro plastic pellets in Tinnakkara Island were found three times higher than in Chennai, white pellets were found in Tinnakkara Island while as yellow resin pellets were found in Chennai which indicate that the resin pellets yellow in colour are weathered from a long time which lead to their color change and adhesion of other substances to their surface, whereas white resin pellets are in water for less time and has not been weathered for long time. The study concludes that the presence of resin pellets in Tinnakkara Island could be because of international routes and deposits by oceanic currents.

A.Vidyasagar et al., [20], conducted a study on macro debris and micro plastic distribution in Rameswaram Coral Island in India. The study showed the presence of white coloured and irregular shaped plastic debris dominated the waters. The study suggested that the micro plastic pollution could be due to tourist activity and fishing activities in these areas. The collected micro plastics were identified by FTIR Spectroscopy and polypropylene was found to be dominant polymer diversity. The study concludes that the white coloured micro plastics could be because of the plastic bottles which get washed away or are carried by winds to the water. S.KrishnaKumar et al., [21], conducted a study on the Nallathanni Island in India. Samples collected from different sites showed the presence of microplastics, fibers and household plastic waste including cosmetic scrubbers, insect repellents, resin pellets and sunscreens. The polystyrenes pieces were found in the coral Island due to the action of wind, the micro plastic distribution was found to be less than the coastal distribution. The natures of the plastic samples were identified using FTIR Spectroscopy. Ashwini S.K, George K. Varghese et al., [22], conducted a study on microplastic pollution in Nattika Beach Kerala. The prominent type of plastic found in this study from the samples was polyethylene and red pellets were found which could be because of nearby industry. Mostly the microplastics were secondary in nature; the authors used forensic investigation strategy for identification of sources. Keziya James et al., [23], conducted a study on assessment of microplastics in ecosystem and on commercially important fishes of Kochi, India. The study found that the microplastics in surface waters was present in abundant season, the concentration of MP’s was higher in monsoon season. The commercially important fishes like Sardinella longiceps, S.gibbosa, Stolephorus indicus Rastrelliger kanagurta and Cyanoglossus macrostomus, were examined and the microplastic particles of size 0.27 mm-3.2mm were found in the gut of these fishes which show the severe threat to these living organisms. The authors used Raman spectroscopy to identify the microplastics and polypropylene and polyethylene were found to be present in fish gut. S.Selvam et al., [24] conducted a baseline study on the presence of microplastics in marine salts in the Tuticorin Costal salt pan station in India. The authors collected 25 samples from the salt pans and microplastics were identifies and separated by hand picking, visual classification and by using µ FTIR Spectroscopy, AFM. Microplastics of size 100µm were found in salt samples, the order of the plastic in the samples was polypropylene > polyethylene > nylon > cellulose. The study concludes that the table salt used by humans on daily bases was found to be contaminated with microplastics which pose a high risk of severe human health issues. R.S.Robin et al., [25] conducted a study on the holistic assessment of microplastics in coastal environmental matrices’, south east cost of India. The study has shown the presence of microplastics in water due to river run off and the mostly dominated by polyethylene and polypropylene as identified by using FTIR-ATR Spectroscopy. The authors also studied the presence of microplastics in the commercially important fishes and 15 out of 70 fishes carried 22 microplastic particles in their guts. Apart from these heavy metals and other metalloids were found on microplastics collected from Kerala beaches which indicate the hazardous nature of microplastics. So far only one study has been carried out in India by S.Sruthy, E.V.Ramasamy [26] in Kerala. The study was actually a short communication, which showed the presence of micro plastics in lake sediments dominated by low density polyethylene. The polymer components were identified by using micro Raman Spectroscopy. The study concludes that the micro plastics could be ingested by the fishes present in the lake which are used by the local population as protein source and pose serious threat for contamination of food web of this lake. Marine water ecosystems have mostly been studied in India, but the extent of the micro plastic pollution in the marine waters has not been shown. In most of the studies impact of these emerging pollutants have been neglected which could be used as an initiative for further study on micro plastics. Only few marine studies have been carried in some parts of India while the other parts still remain unstudied for micro plastic pollution. Last but not the least, the data on fresh water ecosystem contamination by micro plastics is very scare and need is felt to study the fresh water lakes, which could help in recognizing the possible threat to the
fresh water ecosystem organisms which in turn can cause life threats to humans.

2. Sources and Exposure of Microplastics

The sources of microplastics sources in the environment is abundant and their existence is established by analyzing or taking plankton samples, examining surface and sediment samples and observing their consumption by living organisms [9]. Many common sources of the microplastics are listed below:

a) Sewage Treatment plants:

The main purpose of the sewage treatment plants is to treat the waste water; the primary sources of these wastes are usually house wastes. The waste water is treated by using many chemical and biological processes [27], the physical processes are used to separate the solid and suspended materials from the wastes. The biological processes use bacteria for the breakdown of organic matter (waste water treatment manuals, Ireland 1997). Microplastics are found in both primary and secondary wastes, which are somewhat less in the secondary, many studies have suggested that most of the microplastics are removed from the waste water with an efficiency of 99.9 % [27].

b) Wear and tear of tires:

Wear and tear of tires usually the car tires has been estimated 0.23 to 4.7 kg per year and global average of 0.81 kg per year. It has been found that the emission from car tires is higher than those of the other sources which add to the microplastic contribution. According to the study conducted by WHO these microplastics from tire wear and tear are blown away by wind to the oceans which enter our food chain and cause deaths. Further studies need to be carried out to see the impact on human beings [28].

c) Cosmetic products:

Many cosmetic products used in daily life by us like scrubs, tooth pastes and face washes contain small microplastics called as microbeads. These microbeads are tiny in shape and can pass through the sewage easily; these microbeads are made up of polyethylene which is the common constituent of plastics. About 0.7 microbeads per liter are discharged in the water every day, this problem starts at the house hold level and then to the environment. It has been estimated that 808 trillion microbeads are released in the water per day from the house hold waste water. Some products are still sold by many companies with microbeads without mentioning in the labels. Microbeads have been found to absorb many harmful chemicals like pesticides and insecticides which can prove fatal to the aquatic life [29,30].

d) Clothes:

Washing clothes also contribute to the addition of microfibers in the environment, it’s been found that a single garment can shed 1900 microfibers with fleece [31], these microfibers can get suspended in air and can cause serious health problems in elderly people and children. They also go by washing into the water and get accumulated in zooplanktons and then in whales and act as threat to aquatic life [32].

e) Plastic bottles and packaging materials:

We the modern people shop a lot usually online, all our products comes in packaged polythene which is manufactured by using polyethylene. We usually dump them either in open, sooner or later they are either carried or blown by wind to the water or either gets weathered and breaks into smaller pieces. These are then ingested by small aquatic organisms and get accumulated in their organs causing organ failure in them. Similarly plastic bottles are used in everyday life either to drink water or cold drinks finally end in the water because of lack of proper disposal. Marine organisms are usually either get suffocated or entangled leading to the death because of these microplastics. These plastic bottles undergo weathering in the water and gets disintegrated into smaller plastic particles which are ingested by many aquatic organisms leading to their death, these plastic bottles are not only found in marine water but also in fresh waters [33].

3. Ingestion and Accumulation of Microplastics

Plastics have become a vital part of our lives as they are light in weight, easy to carry, durable, cheap and non-corrosive. Due to improper disposal of these plastics they end in the water bodies, where due to various biological, physical and chemical changes they get fragmented into smaller pieces called as microplastics [34,35]. These microplastics have been seen to be ingested mostly by fish, which often misinterpret them as food due to their colour. The ingestion of microplastics usually happens with the ingestion of natural food [36] or when they feed on their prey where it was already present in prey body [37]. They usually get accumulated in the gut, stomach and intestinal lining causing hepatic stress, neurotoxicity and in some cases mortality [38]. It also causes the tropic transfer of these microplastics from one food chain to other.

4. Impact of Microplastics on Marine and Fresh Environments

Microplastics become a point of concern with the reduction of their size, as they are easily ingested by aquatic organisms such as planktons, fishes, whale’s mussels and also by various birds and mammals leading to their accumulation in food web [11]. The microplastics were fed to the different aquatic organisms under laboratory conditions and the effects were studied. W.Sanchez et al., [39] investigated (fresh water) gudgeon (Gobio gobio) caught from the 11 streams and 12% among them contained microplastics in the digestive tract. Usually the amount or concentrations of microplastics in different organisms differ with their feeding approach. Rosenkranz et al., [40], conducted a study on water flea (Daphnia magna) under laboratory conditions, it was found that it ingests microplastics hastily and latter got accumulated in the epithelium in the form of lipid droplets. Many studies suggest that toxicological effects of microplastics in fresh water remain uninvestigated
and need is felt to do the same as less literature is available on fresh water. In marine environments lots of studies have been carried out, bivalves such as blue mussels filter about two liters of sea water every hour and were found to carry microplastics which were assumed to be because of the plastic ropes used to grow them. It was consumed by humans; they will be ingesting 90 particles of microplastics [41]. Barnacles are suffocation in small crustaceans who are suspension feeders they were found to contain microplastics that too in tangled balls which caused tangling and suffocation in them (Norwegian institute of water research). The effects of microplastics on the marine organism have been shown to be sub-lethal which means less feeding and the microfibers have seen to block the digestive system of the organisms [11]. Many studies have shown hepatic stress and reduction in efficiency of reproductive activities in fishes. Due to their large surface volume and chemical composition microplastics can accumulate many contaminants and chemicals including metals and accumulate toxic compounds [42]. The microplastics act as vector for many microorganisms which can lead to the spread of many water borne diseases [43].

![Pie chart showing the number of studies in India in last 8 years](image)

**Figure 1.** Pie chart showing the number of studies in India in last 8 years

| Sno. | Location                          | MP range       | Types of samples | Type of MP               | Reference |
|------|----------------------------------|----------------|-----------------|--------------------------|-----------|
| 1    | Vembanad Lake, Kerala            | 252.8 particles m⁻² | Sediment sample  | HDPE, LDPE, PP, PS       | [26]      |
| 2    | Nallathanni Island, Gulf of Mannar | 149.7 particles m⁻² | Surface sample   | PE, PVC, Nylon, PS       | [21]      |
| 3    | Kochi, south eastern Arabian sea | 76.59 m⁻²         | Fishes           | Filaments, fragments and pellets | [23]      |
| 4    | Goa coast                        | 3000 pieces      | Surface          | Plastic films, fragments and pellets | [18]      |
| 5    | West coast of India(Maharashtra) | 346m⁻²           | Surface          | PP, PE                   | [44]      |
| 6    | Rameswaram coral island          | 403 pieces       | Sediments        | PP, PE, PS, PVC, Nylon   | [20]      |
| 7    | Mumbai                           | 3 pieces         | Surface          | PP, PVC, PE              | [45]      |

**Table 1.** The summary of some microplastic contamination in Indian fresh and marine waters in different years
5. Conclusion

The main purpose of this paper was to enlighten the knowledge gaps and lack of availability of literature and information on microplastics. The marine ecosystems have been studied on a wider extent world wide than the fresh water ecosystems for the presence of micro plastic pollution. In India marine environment is studied extensively than fresh water, various papers were studied and it was concluded that the extent of the micro plastic pollution in marine water ecosystems have not been evaluated and many studies have not shown the extent of effect of the micro plastic pollution on food webs. Need was felt to evaluate the presence and effects of micro plastic pollution in fresh water ecosystems which could help in recognizing their nature and effects on various organisms and humans. The toxic effects and biomagnifications of microplastics through different food chains needs to be evaluated, more studies should be conducted to reduce the hazardous effects on the marine as well as aquatic environments. Development of new assessment techniques should be done from microplastic assessment.

Compliance of Ethical Standards

This review article does not contain any studies involving human participants performed by any of the authors.

References

[1] Andrady AL, Neal MA (2009). Applications and societal benefits of plastics. Philos Trans R Soc Lond B Biol Sci, 364: 1977-1984.
[2] Carpenter, E.J., Smith, K.L., 1972. Plastics on the Sargasso Sea surface. Science 175, 1240-1241.
[3] Coel, M.Lindeque, P, Halsband, C, Gallow, T.S (2011). Microplastics as contaminants in marine environment: a review. Mar. Pollution. Bul. 62 (12), 2588-2592.
[4] Thompson, R.C., Olsen, Y., Mitchell, R.P., Davis, A., Rowland, S.J., et al., 2004. Lost at sea: where is all the plastic? Science 304, 838.
[5] Boucher, Julien; Friot, Damienn (2017). Primary microplastics in oceans: a global evaluation of sources. IUCN. Gland, Switzerland.
[6] Jeremy L Conkle, Christian D Baer Del Valle, Jeffery W Turner. (2018). Are we underestimating microplastic contamination in aquatic environments. Environmental management 61 (1), 1-8.
[7] Rowsbyra A Castaneda, Sunicina Avlijas, M Anouk Simard, Anthony Ricciardi. (2014). Microplastic pollution in St. Lawrence river sediments. Canadian journal of fisheries and aquatic sciences 71 (21), 1767-1771.
[8] Mato, Tomohiko Isobe, Hideshige Takada, Haruyuki Kanehiro, Chiyoko Ohtake, Tsunghika Kaminuma, (2001). Plastic resin pellets as a transport medium for toxic chemicals in the marine environment. Environ science and technology 35(2), 318-324.
[9] Ivar do Sal, J.A.L, Costa, M.F, 2014. The present and future of microplastic pollution in the marine environment. Environ. Pollut. 185, 352e364.
[10] Eerkes-Medrano, D., Thompson, R.C., Aldridge, D.C., (2015). Microplastics in freshwater systems: a review of the emerging threats, identification of knowledge gaps and prioritization of research needs. Water Res. 75: 63-82.
[11] Wright, S.L, Rowe, D, Thompson, R.C., Galloway, T.S., 2013a. Microplastic ingestion decreases energy reserves in marine worms. Curr. Biol. 23, R1031-R1033.
[12] Sumaila, U.R., Khan, A,Watson, R., Munro,G., Zeller, D., Baron, n., Pauly,D, (2007). The world trade organization and global fisheries sustainability. Fish. Res.88, 1-4.
[13] Hirai, H., Takada, H., Ogata, Y., Yamashita, R., Mizukawa, K.,Saha, M., et al. (2011). Organic micropolliutants in marine plastics debris from the open ocean and remote and urban beaches. Marine Pollution Bulletin, 62(8), 1683-1692.
[14] Jhanke et al (2017). Reducing uncertainty confronting ignorance about the possible impacts of weathering plastic in Marine environment. ENV Science and Tech, 4, 3, 85-90.
[15] Keswania, A., Olivera, D., Gutierrez, T., Quilliam, R.S., 2016. Microbial hitchhikers on marine plastic debris: human exposure risks at bathing waters and beach environments.Mar. Environ. Res. 118, 10e19.
[16] K-Vristien, Sidika Kirmiezi, Antje Wichels, Alexa Garin-Fernandez, Rene Erelre, Martin Loder, Gunnar Gerds. (2016). Dangerous hitchhikers? Evidence for potentially pathogenic Vibrio spp on microplastic particles. Marine pollution bulletin. 120, 1-8.
[17] Jayasri, H. B., Purushotharan, C. S., and Vennila, A. (2013). Plastic litter accumulation on high-water strandline of urban beaches in Mumbai, India. Environmental Monitoring and Assessment 185(9): 7709-7719.
[18] S. Veerasingam, Mahua Saha, V. Suneel, P. Vethamony, Andrea Carmelita Rodrigues, Sourav Bhattacharyya, B.G. Naik, (2016). Characteristics, seasonal distribution and surface degradation features of microplastic pellets along the Goa coast, India. Chemosphere vol, 159.
[19] M.Mugilarasan, R Venkatachalapathy, N Sharmila, K Gurumoorthi, (2017). Occurrence of microplastic resins from Chennai and Tinnakkara Island:Towards the establishment of background level for plastic pollution. NISCAIR-CSIR, India.
[20] A. Vidyasakarra, K. Neelavannab, S. Krishnakumar, G. Prabhaharana, T. Satyiahbama Alias Priyankad, N.S. Maghes, Prince S. Godsonf, S. Srinivasulac, (2018). Macrodebris and microplastic distribution in the beaches of Rameswaram Coral Island, Gulf of Mannar, Southeast coast of India: A first report. Marine POLLUT Bulletin 137.
[21] S.KrishnaKumar, S. Srinivassubh, P. Saravanana, A. Vidyasakarra, N.S. Mageshd, (2018). A preliminary study on coastal debris in Nallathanni Island, Gulf of Mannar. Biosphere Reserve, Southeast coast of India. Marine Pollut Bulletin 131.
[22] Ashwini S. K. and George K. Varghese, (2020). Environmental forensic analysis of the microplastic pollution at “Nattika”Beach, Kerala Coast, India. ENVIRONMENTAL FORENSICS 2020, VOL. 21, NO. 1, 21-36.
[23] Keziya James, Kripa Vasant, Shelton Padua, Vineetha Gopinath, Abhas K.S, Jeyakabaran R, Akhil Babu, Seban John, (2020). An assessment of microplastics in the ecosystem and scelencted commercial fishes of Kochi, south of eastern Arabian sea,India.Marine pollution Bulletin vol 154.
[24] S.Selvam, A Manisha, S Venkataramanan,SY Chung, CR Paramasivam, C Singaraja, (2020). Microplastic presence in commercial marine sea salts: A baseline study along Tuticorin costal salt pan stations, Gulf of Mannar, South India. Marine pollution bulletin 150.
[25] R.S. Robin, karthik, R Purvaja, D Ganguly, I Anandavelu, M Mugilarasan, Ramesh, (2020). Holistic assessment of microplastics in various coastal environmental matrices, South coast of India. Science of the total environment 703, 134947.
[26] S.Sruthy, V.Kristein, Sidika Kirmizi, Antje Wichels, Alexa Garin-Fernandez, Rene Erelre, Martin Loder, Gunnar Gerds. (2016). Dangerous hitchhikers? Evidence for potentially pathogenic Vibrio spp on microplastic particles. Marine pollution bulletin. 120, 1-8.
[27] Fendall, Lisa S; Swell, Mary A. (2009). “Contributing to the microplastics debris from the open ocean and remote and urban beaches. Marine Pollution Bulletin, 62(8), 1683-1692.
[28] Carr, S.A, Liu, J, Tesoro,A.G. 2016. Transport and fate of microplastics in waste water treatment plants. Water Res. 91, 174-182.
[29] Cole, Pieter Jan, Lohr, Ansje J, Van Belleghem, Frank; Ragas, Ad M.J. (2017). “Wear and tear of tires: A Stealthy source of Microplastics in the Environment”. International Journal of Environmental Research Public Health.
[30] Anderson, A.G; Grose, J; Phal, S; Thompson, R.C; Wyles, K.J. (2016). Microplastics in personal care products: Exploration perceptions of Environmentalists, beauticians and students. Marine Pollution Bulletin.
[31] Katsnelson, Alla (2015). “News Feature: Microplastics present pollution puzzle”. Proceedings of national academy of sciences. 112 (18): 5547-5549.
[32] Browne, Mark Anthony; Crump, Phillip; Niven, Stewart J.; Teuten, Emma; Tonkin, Andrew; Galloway, Tamara; Thompson, Richard (2011). “Accumulation of Microplastic on Shorelines Worldwide: Sources and Sinks”. Environmental Science & Technology. 45 (21): 9175-9179.
[33] Baldwin, Austin K.; Corsi, Steven R.; Mason, Sherri A. (2016). "Plastic Debris in 29 Great Lakes Tributaries: Relations to Watershed Attributes and Hydrology", Environmental Science & Technology. 50 (19): 10377-10385.
[34] Zhao, Lixin Zhu, Daoji Li. (2015). Microplastics in three urban estuaries, China. Environmental pollution 206.
[35] Su, Y Xue, L Li, D Yang, P Kolandhasamy, Daoji Li, Huahong Shi. (2016), Microplastics in Taihu lake, China. Environmental Pollution 216, 711-719.
[36] Peter, C.A, Bratton, S.P, (2016). Urbanization ia a major influence on microplastic ingestion by sunfish in the Brazos River basin, Central Texas, USA. Environ Pollut. 210, 380-387.
[37] Cedarville, T., Hansson, L.-A, Lard M Frohm, B., Linse, S., (2012). Food chain transport of nanoparticles affects behavior and fat metabolism in fish. PLOS ONE 7, e32254.
[38] Luis Carlos de Sa, Miguel Oliveria, Francisca Ribeiro, Thiago Lopes Rocha, Martyn Norman Futter, (2018). Studies of the effects of the microplastics on aquatic organisms: what do we know and where should we focus our efforts in future? Science of the Total Environment, vol 645.
[39] Wilfried Sanchez, Coline Bender, Jean-Marc Porcher. (2014). Wild gudgeons (Gobio gobio) from French rivers are contaminated by microplastics: preliminary study and first evidence. Environmental research 128,98-100.
[40] Rosenkranz P, Chaudhry Q, Stone V, Fernandes TF, (2009). A comparison of nano particles and fine particles uptake Daphnia magna. Environ Toxicol Chem, 28:2142-2149.
[41] Alysse Mathalon, Paul Hill. (2014). Microplastic fibers in the intertidal ecosystem surrounding Halifax Harbor, Nova Scotia.Marine pollution bulletin 81 (1), 69-79.
[42] Ashton K, Holmes L, Turner A, (2010). Association of metals with plastic production pellets in the marine environment. Mar Poll Bull, 60: 2050-2055.
[43] Carson H S, Nerheim MS, Carroll KA, Eriksen M. (2013). The plastic associated microorganisms of the north Pacific Gyre. Marine pollution bulletin. 75: 126-132.
[44] Dusmant Maharana, Mahua Saha, Jaffer Yousuf Dar, Chavanika Rathore,RA Srpada,Xiang-Rong Xu,J.Bimali Koonglla, Heng-Xiang Li. (2020). Assessment of microplastics along the west coast of India: Abundance, distribution, polymer type and toxicity.Chemosphere 246, 125708.
[45] H B Jayasiri, CS Purushhotaman, A Vennila. Quantative analysis of plastic debris on recreational beaches in Mumbai, India. (2013). Marine pollution bulletin 77(1-2) 107-112.