

PREVALENCE AND HUMAN HEALTH RISK ASSESSMENT OF MICROPLASTIC CONTAMINATION IN FRESHWATER FISH PRODUCTS OF CHHATTISGARH, INDIA

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ABSTRACT

This study evaluates the prevalence and morphological characteristics of Microplastic (MP) contamination across the freshwater aquatic resources of Chhattisgarh, India, and assesses the resulting human health risks. Utilizing a sampling framework of 60 specimens categorized into community ponds, cultivated fish farms, and processed fish products (n=20 each), the research reveals near-ubiquitous contamination. Findings demonstrate a 100% prevalence rate in community ponds and a 90% prevalence in processed products, while private fish farms showed a significantly lower occurrence of 65%. Processed fish products exhibited the highest weight-based contamination (4.85 ± 2.52 MP/g). Physical analysis identified Grade III (0.3mm–0.01mm) particles and fragments as the dominant size and morphological classes, respectively. Human health risk assessments, calculated via per capita consumption rates, indicate that rural populations face higher annual ingestion risks (6,201.6 particles/year) compared to urban populations (3,876 particles/year). These data emphasize the urgent need for standardized monitoring of MPs in freshwater food chains to mitigate long-term toxicological impacts on public health.

KEYWORDS: MPs; Freshwater fish; Human health risk assessment; Aquatic pollution; Chhattisgarh.

1. INTRODUCTION

Microplastic (MP) contamination has become the most prominent environmental issues that affect the aquatic ecosystem globally. MP comes about from the breakdown of plastics into tiny pieces or is produced as primary MP through direct input into the environment. MP remains in the environment due to its degradation-resistant nature and distribution throughout freshwater and marine environments (Andrade et al., 2019; Andrady, 2017; Barboza et al., 2018). Freshwater ecosystems are more susceptible because of constant inputs of plastics in rivers, lakes, ponds, and reservoirs due to domestic, urban, agricultural, aquacultural, and industrial sources. The presence of MPs in the aquatic ecosystem means that they can be easily ingested by organisms including fish either from the water itself or via prey items (Campbell et al., 2017). This is a source of great concern due to the consumption of fish being the main source of protein for millions of people in the world (Cox et al., 2019). Research work in India has also established the presence of MPs in the edible fish tissues that are sold to the human population, which highlights the possible health effects that are linked to the consumption of fish via the diet (Daniel et al., 2020). There is also experimental evidence suggesting that consumed MPs can lead to oxidative stress, inflammatory reactions, and tissue damage, which highlights the importance of comprehending the long-term biological impacts of MPs (Deng et al., 2017). Additionally, freshwater ecosystems have gained a growing reputation as significant sources and routes of MPs, which must be systematically monitored to know their ecological distribution and environmental destinies (Dris et al., 2015; Eerkes-Medrano et al., 2015). The standardized definitions and classification systems have also enhanced the uniformity of the research on MP, thus allowing effective comparisons between the studies which have been carried out in different geographical locations (Hartmann et al., 2019).

Although there is increasing awareness across the world, there is a massive understanding gap as far as MP contamination in freshwater fisheries is concerned, especially in developing countries. Past studies have shown that the ingestion of MPs differs significantly across fish species, habitats, feeding behavior, and environmental factors, and it is hard to extrapolate the covariance of contamination patterns across freshwater ecosystems (Horton et al., 2018). Despite the innovations in the methods of analysis, the distribution of MPs in inland fisheries has a small amount of information in most areas (Ivleva

et al., 2017). The available research has mostly concentrated on marine conditions or on the chosen freshwater conditions, and overall evaluations that combine occurrence, particle properties, and exposure hazards in freshwater food resources are limited (Jabeen et al., 2017). In India, the existing studies have focused on coastal ecosystems and commercially significant marine fishes with inland aquaculture and freshwater fisheries underrepresented (James et al., 2020). Moreover, despite many studies that have reported the ingestion of MP by fish, few have associated the level of contamination to the possible harm to human health associated with regular fish consumption (Jovanović, 2017).

One of India's biggest inland fish-producing states is Chhattisgarh, with a large system of rivers, reservoirs, village ponds, as well as aquaculture systems that contribute to food security and the livelihood in rural areas. The freshwater resources of the state support a fast-growing fisheries industry and are regarded as a significant source of animal protein used by a significant percentage of the populace. However, there is a dearth of knowledge regarding the prevalence, nature, and possible human health belongings of MP contamination of these freshwater sources. Other studies have found MP pollution in dry fish products (Karami et al., 2017), freshwater fishes in various parts of India (Kumar et al., 2018), freshwater ecosystems across the globe (Li et al., 2018), freshwater lakes in South India (Manikanda Bharath et al., 2021), and in river fish populations (McNeish et al., 2018). However, there is no systematic evaluation comparing community ponds, cultivated fish farms and processed freshwater fish products together in Chhattisgarh that has estimated potential dietary exposures between rural and urban populations. This gap is critical to addressing the patterns of regional contamination and evidence-based management approaches that can be used to preserve freshwater food resources and human well-being.

Objectives of the Study

1. To regulate the prevalence of MPs in freshwater fishes and processed fish products in Chhattisgarh.
2. To characterize microplastics based on their size and morphological types.
3. To assess potential human health risks linked with MP ingestion through fish consumption.

2. METHODOLOGY

2.1 Study Area

The investigation was done in seven districts of Chhattisgarh, India, viz., Raipur, Rajnandgaon, Korba, Durg, Jagdalpur, Bilaspur, and Janjgir-Champa. These districts were chosen because of their proximity to the state's principal river systems, which include the Shivnath, Mahanadi, Hasdeo, Kharun, Indravati, and Arpa rivers.

2.2 Study Design

The focus of this experiment was to analyze the prevalence of MP uncleanness in freshwater fishes and processed fish products from various sources in Chhattisgarh. The experiment used 60 samples and was divided into three equal groups, namely community pond fishes (n=20), fish farm samples (n=20), and processed fish products (n=20).

2.3 Sample Collection

The sample of fish from community pond were collected from village ponds using the assistance of local fishermen and fish vendors. The fish samples from cultivated sources were collected from private aquaculture farm while the processed fish samples, which were mainly dried and crude fish samples, were collected from local market. In order to keep uniformity among all the fish samples collected, fish samples ranging between 3-8 cm in size were collected. Before being analysed in the lab, all collected samples were transported in ice boxes to the laboratory and stored at -20°C.

2.4 MP Classification

The MPs were divided according to their morphology and size. MPs were segregated into grades depending upon their size as Grade I (5–1 mm), Grade II (1–0.3 mm), and Grade III (0.3–0.01 mm). The five different morphologies of MPs include fragments, fibers, pellets, films, and sheets.

2.5 Data Analysis

The contamination with MPs was assessed based on the percent positive samples for each sampled population. The density of MPs was indicated by the mean number of particles per gram of sample (MP/g) and the mean number of particles per fish (MP/fish) with the standard deviation (Mean ± SD). The difference in MP abundance between the sampled populations was examined using one-way ANOVA, with the level of statistical significance at $p < 0.05$.

2.6 Human Health Risk Assessment

An indirect method based on annual per capita fish consumption was used to evaluate the risk to human health. The following formula was used to regulate the yearly consumption of MPs:

$$\text{Per capita annual MP consumption} = (\text{Per capita fish consumption per annum}) \times (\text{MP concentration per kg})$$

The yearly fish consumption rates for Chhattisgarh's rural and urban populations were used in the study to calculate the possible dietary exposure to MPs.

3. RESULTS

3.1 Occurrence of MPs in Different Samples of Fish

There was variation in the presence of MPs in each sample of fish categories. As shown in Table 1, the fish sampled from the community pond had the highest rate of contamination, while the fish from fish farms had the lowest. The processed

fish had the highest concentration of MPs per gram, while fish from fish farms had the least concentration. The one-way ANOVA test showed that there was a statistical alteration ($p < 0.05$) in the amount of MPs per gram between community pond and fish farm samples.

Table 1. Occurrence of MPs in different fish sample groups

Sample Group	Total Samples	Positive (%)	MP per Gram (Mean \pm SD)	MP per Fish (Mean \pm SD)
Community Pond	20	100	4.01 \pm 1.42	12.05 \pm 4.26
Fish Farm	20	65	0.68 \pm 0.62	14.10 \pm 11.99
Fish Product	20	90	4.85 \pm 2.52	15.45 \pm 7.41

Figure 1 provides a visual comparison of the percentage of positive samples and further illustrates the frequency of MP contamination among the three sample groups.

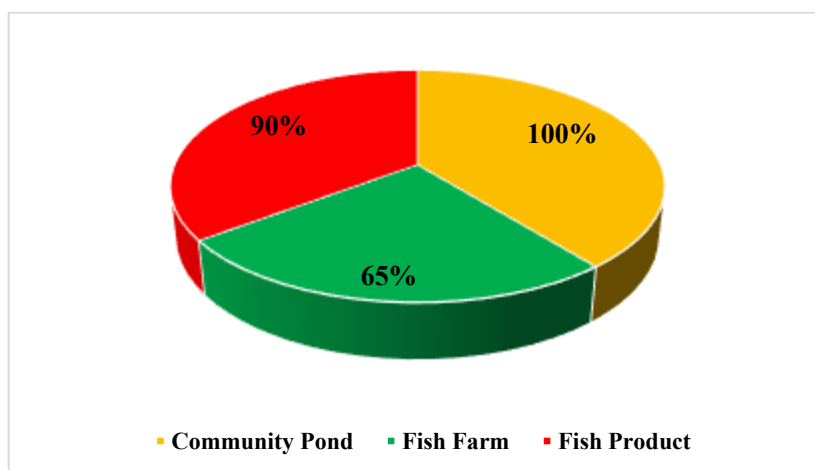


Figure 1. MP-positive samples

As shown in Figure 1, there is an evident difference in the prevalence of MPs between the three fish sampling populations, which shows that MP contamination is higher in community pond fish and fish processing products than in farmed fish populations.

3.2 Distribution of MPs (Size-wise)

The MPs found were sorted based on their size into three categories: Grades I, II, and III to regulate the distribution of the elements in various fish sample categories. Figure 2 displays the distribution percentages of each size of MPs found in community pond fish, fish farm samples, and processed fish samples.

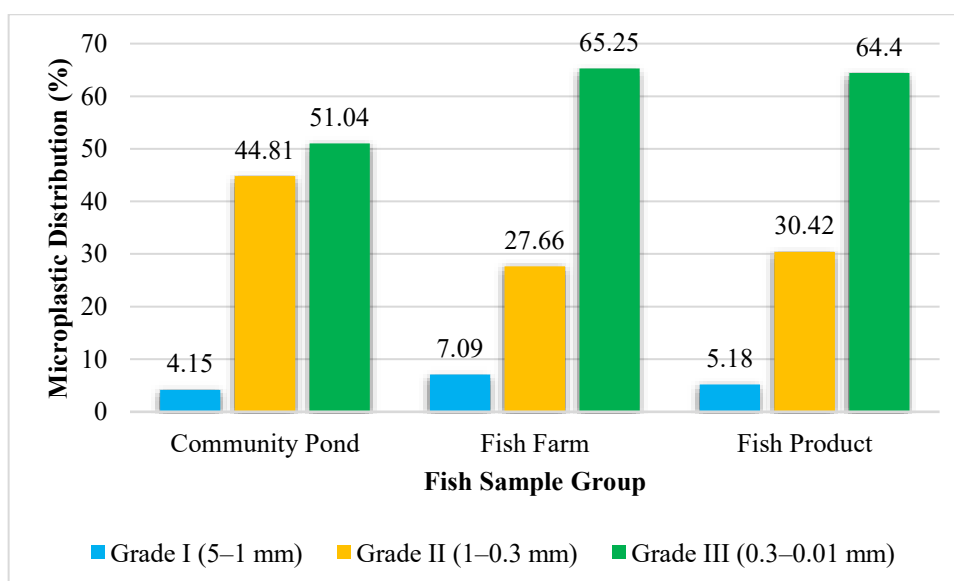


Figure 2. Size-wise occurrence of MPs (%)

Figure 2 shows the percentage composition of the three MP size fractions among the various fish sample fractions. Grade III plastic (0.3-0.01 mm) was the highest percentage of MPs found in all fish sample fractions with a composition of 51.04% of community pond fish samples, 65.25% of fish farm samples, and 64.40% of processed fish products. Grade II plastics were the second highest fraction of MPs while Grade I was the lowest in composition.

3.3 Morphological Distribution of MPs

Table 2 provides a description of the morphological features of the recovered MPs. Fragmentation was the most frequent morphological feature of MPs found in all sample types, comprising 66.39% of MPs in community pond fish, 53.90% of MPs in fish farm samples, and 69.45% of MPs in processed fish. Fiber was the next most common morphological feature of MPs, while pellets, film, and sheet were rarely found.

Table 2. Morphological distribution of MPs (%)

MP Type	Community Pond	Fish Farm	Fish Product
Fragments	66.39	53.90	69.45
Fibers	32.37	45.04	30.55
Pellets	0.41	0.35	0.00
Films	0.41	0.00	0.00
Sheets	0.41	0.71	0.00

3.4 Human Health Risk Assessment

3.4.1 Estimated Annual MP Ingestion

The annual estimate of MPs ingestion was based on annual per capita fish consumption among the rural and urban population of Chhattisgarh. The estimates were 6,201.6 particles/year for the rural population and 3,876.0 particles/year for the urban population, as presented in Figure 3.

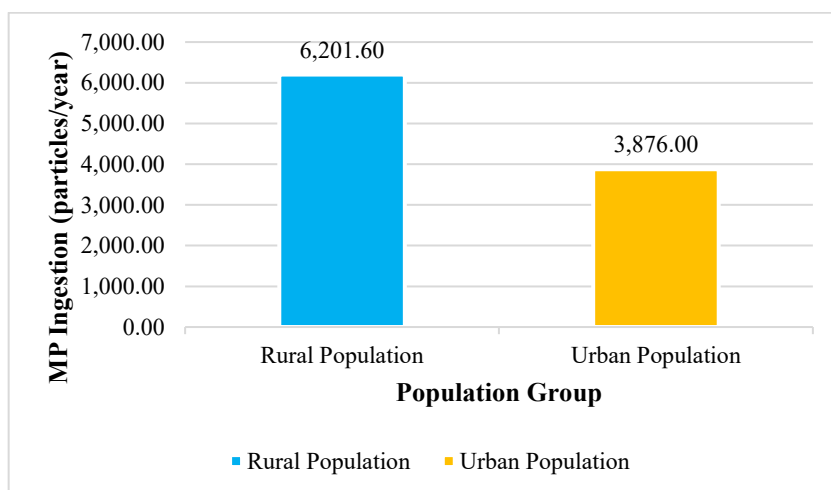


Figure 3. Estimated annual dietary exposure to MPs among rural and urban populations

Annual intake estimate of MPs by rural and urban inhabitants of Chhattisgarh via per capita fish consumption is shown in Figure 3. It was found that the estimated annual intake in rural population is relatively higher compared to the urban population.

3.4.2 Source-wise Exposure Assessment

The annual dietary exposure estimation was found to differ based on the kind of fish eaten. The consumption of processed fish led to the highest estimates of the annual MPs intake at 9,312 particles/year for the rural consumer and 5,820 particles/year for the urban consumer. On the contrary, the cultivation fish had the lowest annual estimates at 1,305.6 particles/year for the rural consumer (Table 3).

Table 3. Estimated annual MP ingestion according to fish source

Fish Source	Rural Population (particles/year)	Urban Population (particles/year)
Processed Fish Products	9,312.0	5,820.0
Cultivated Fish Farms	1,305.6	-

4. DISCUSSION

In the current investigation, the prevalence of MPs in freshwater fish and processed fish samples from various aquatic sources in Chhattisgarh was assessed. Community pond fish had the maximum prevalence of MPs contamination associated to the samples of fish cultivated from fish farms, which indicated lower MP contamination. The high prevalence of MPs contamination in community pond fish can be related to continuous plastic pollution of the aquatic sources from household activities, surface run-off, and poor water exchange in the enclosed water bodies. At the same time, privately-owned fish farms usually have a more controlled environment for fish production, thus reducing the chances of the entry of plastic waste into these water bodies. Fish samples that underwent the processing steps showed the highest MP concentration per weight, indicating that the contamination of fish can take place not only in the aquatic environment but also during the post-harvesting stages such as processing, packaging, and marketing. Moreover, the presence of Grade III

MPs suggests that smaller plastics form the larger portion of contamination, thus raising the risk of ingestion by eating fish.

The outcomes of the current work are in agreement with the previous literature that describes the prevalence of MPs in freshwater fishes in various geographical areas. The existence of MPs in riverine fish in the Han River, South Korea, reported by Park et al. (2020), indicates that freshwater organisms are constantly exposed to plastic pollution. On the same note, Parvin et al. (2021) noted a significant variability in MP content and properties among freshwater fish in Bangladesh as they established the ubiquitous presence of MPs in inland water. Significant burdens of MP were also reported by Roch et al. (2019) in freshwater fishes in south-western Germany, highlighting the fact that freshwater ecosystems are now significant sources of plastic pollution. The preponderance of fragments found in the current study is in line with the international picture outlined by the study of the report by Sequeira et al. (2020), who also reported fragments as some of the most commonly found MP morphologies in fish globally. Similarly, Sharma and Chatterjee (2017) proposed that a significant source of secondary MPs into the aquatic environment is fragmentation of larger plastic debris. Su et al. (2019) also showed the presence of MPs in various organs of fish, which indicates the possibility of dietary exposure in consumers. Besides this, Toussaint et al. (2019) also identified fish as a significant route of MP movement throughout the food web and Wagner et al. (2014) have also highlighted the ecological importance of freshwater ecosystems as a key sink and a transport system of MP pollution.

The high presence of MPs with grade III (0.3–0.01 mm) found in the current research is particularly worrying due to their tiny size that could lead to increased chances of ingestion via fish consumption. The fine-sized MPs could have more potential interactions with the biological tissues after ingestion and contribute to biological adverse effects upon continuous exposure. While the exact health risks associated with dietary exposure on a continuous basis are not entirely known yet, the dominance of the particles in fresh water fish requires further investigations.

This study has significant environmental, and public health implications. Freshwater fish are a significant source of dietary protein to a significant percentage of the population in Chhattisgarh especially in rural areas. The projected intake of 6,201.6 MP particles per annum by rural consumers, therefore, suggests that chronic dietary exposure has a higher potential among rural consumers than the urban population. Additionally, the entire contamination of the community pond fish indicates that these freshwater environments might be an unbroken exposure route to the surrounding communities. The high contamination revealed in processed fish products is yet another indication that hygiene practices should be enhanced in the processing, storage, packaging, and marketing of fish products. Plastic waste management methods, development of environmental friendly aquaculture practices and a regular monitoring program are thus necessary to reduce pollution of fresh water food resources.

There were various limitations of the present investigation. For instance, the number of samples analyzed in the current study was fairly small in numbers since they were taken from selected areas of Chhattisgarh. Moreover, there was no identification of polymer content and the chemicals in the MPs that could be dangerous for human health. There was no determination of MPs' effects on human health.

Future research efforts should involve larger sample sizes that incorporate other freshwater ecosystems, different fish species, and seasonal changes for a broader knowledge base on MPs pollution. Advanced methodologies such as FTIR and Raman spectroscopy would enhance polymer analysis and attribution. It would be advisable to future researchers to study the accumulation of MPs within edible parts of fish and the associated chemical pollution that comes along with it and the impacts associated with chronic ingestion. This knowledge would assist in the formulation of proper strategies that seek to minimize the effects of MPs in freshwater ecosystems and safeguard public health.

5. CONCLUSION

This investigation has shown that MPs are common in freshwater fishes and canned fish in Chhattisgarh, which indicates the increasing issue of plastic pollution in inland aquatic food sources. The community pond fish showed the most prevalence of contamination, whereas processed fish products harbored the highest concentration of MP per weight, suggesting environment and after harvesting handling might be involved in contamination. The fact that Grade III MPs and fragment-like particles prevailed implies that smaller plastic debris is the largest type of contamination in the freshwater food chain. The assessment of human health risk also showed that the rural populations had higher annual exposure to diet compared to urban populations, which is reflected in the consumption of fish. All these results highlight the need to enhance the management of plastic waste, hygiene protocols during fish processing and marketing, and periodic surveillance of freshwater fisheries to minimize contamination and ensure food safety. The long-term health impacts of exposure to dietary MPs are yet to be fully understood, although the current study is a valuable piece of baseline data on the prevalence and the possible risks of exposure to MPs in Chhattisgarh. To gain a clearer insight into the ecological and public health impacts of MP contamination in fresh water, future research including larger sample sizes, seasonal analyses, polymer characterization, and toxicology are necessary.

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