BIBECHANA
Vol. 20, No. 1, April 2023, 21–26

ISSN 2091-0762 (Print), 2382-5340 (Online)
Journal homepage: http://nepjol.info/index.php/BIBECHANA
Publisher:Dept. of Phys., Mahendra Morang A. M. Campus (Tribhuvan University)Biratnagar

Overall migration of microplastics in mineral water and non-alcoholic beverages

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Abstract

In today's world, packaging plays a crucial role in enhancing, enclosing, and shielding the materials that are used from procurement to handling and storage, processing, manufacturing and finally to the consumer. Packaging shields a product's contents from contamination, spoiling and makes it simple to store and transfer anywhere. Man-made plastic breaks down into little particles as a result of numerous external pressures. The degradation of plastics produce nano or microplastic. Health issues arise when microplastics (MPs) leak from plastic food packaging and are consumed by people. Though plastic packaging is abundant, consumers from developing nation are not aware of the risk associated with plastic food packaging. The purpose of this study is to demonstrate occurrence of microplastics in plastic food packaging and highlight the risks involved in consumption of microplastics. In this research, the migration of microplastics from different plastic containers were noted in accordance to the Bureau of Indian Standards IS - 9845-1998. The IS 9845: 1998 method was utilized in this investigation to determine the overall migration of various plastics used to package mineral water and beverages. Distilled water and 3 % acetic acid (w/v) were utilized as food simulators for the analysis. The migration of microplastics in mineral water were found to range from 0.38 ppm to 0.54 ppm while in case of non-alcoholic beverages overall migration ranged from 0.29 to 75.75 ppm. Among the 12 samples of non-alcoholic beverages, one sample exceeded the maximum limit of microplastics as specified by WHO standard.

Keywords
Microplastics, simulant, plastic, distilled water, migration .

Article information
Manuscript received: December 22, 2022; Accepted: March 28, 2023
DOI https://doi.org/10.3126/bibechana.v20i1.53457

1 Introduction

Plastics are man made synthetic polymers with different properties like low cost, lightweight, easy to excess, durability etc., due to which plastics are used in our daily life in every aspect from household to large industrial scale [1]. Plastics are used in the pharmaceutical industry, agricultural industries, automobiles, storage, clothing, transportation, packaging, etc. This increases the production of plastics each day [2]. Around 60% plastic packaging is used for food and beverage and rest is used for other purposes like cosmetics, medicines, etc. [3]. During storage and distribution packaging protects food against physical, chemical and biological hazards. Plastics are composed of large organic molecules so they are printable, moldable and heat sealable [4]. Usually plastics used for the packing mineral water and non-alcoholic beverages are polyethylene terephthalate (PET), polypropylene (PP) etc., and belong to thermoplastic group and can be recycled [5]. Ethylene glycol and dimethyl terephthalate under goes polycondensation reaction to give polyethylene terephthalate. This type of plastic is used for packing food and beverages since they are stable towards temperature and moisture [6, 7]. Transferring of chemicals from plastic material to food is known as leaching or migration. It is a process that follows Fick's law of diffusion. Leaching can occur by direct transfer and gas transfer phase [8]. As different layers films are applied in packaging, so the chemicals from the films leach to the drinks through diffusion as well as partition method. The method of leaching chemicals from outer layer of plastic to drink is known as set-off [9]. Plastic is one of the important and useful product in our life and it has made our lives easy in many ways. At the same time it also has negative impact in our life, affecting our health and environment in different ways. Plastic itself is chemically inactive but different additives present in the plastics may cause chemical reactions which lead to migration. When drinks and foods are aggressive, then they react with plastic in which they are packed, in such condition chemicals from plastic leaches to drink [10]. Plastic degrades into small particles like micro and nano plastic by different external forces caused by humans. Article published by Thompson in 2004 where he used the term microplastic which attracts the people's attention [11]. Microplastics once deposited in environment, are difficult to remove. Plastic materials are degraded into microplastics and nano plastics by the photo-oxidation process [12]. Microplastics are plastic particles of various shape, size and dimensions ranging from 1 μm to 5 mm and are not soluble in water [13]. There are two types of microplastics found in our environment, primary microplastic and secondary microplastic. Micro plastics that are manufactured into small size are called primary MPs where as microplastics degraded from large plastic particles are called secondary MPs [14]. Primary microplastics can enter directly to the environment and are made for different purposes such as for cosmetics, industrial use, personal care, cleaning products, beads, plastic pellets etc., and the secondary microplastics are obtained through fragmentation of plastic by aging [15–17]. Presence of microplastic in environment increases pollution and affect the health of living beings and destroys the productivity of soil [18].

In developing nation like Nepal where plastic food packaging is very abundant due to various factors such as lack of alternatives, lack of awareness and busy lifestyle. Due to that microplastic leaching has become an alarming concern for people. Studies and research carried out in advanced nations have properly demonstrated the qualitative and quantitative analysis of microplastic leaching and migration through use of sophisticated tools and apparatus. Those advanced llevel researches have also shown the negative effects caused by microplastic leaching from plastic packaging on human health as well as the environment along with the mitigating measures and alternative approaches. However, in developing nations, these kind of esearches have not been conducted thoroughly with adequate analysis so as to aware people and provide alternatives. This research is conducted on a small scale to highlight the quantitative measurements of microplastic leaching as a result of plastic food packaging and also to relate different kind of impacts it has on environment and human health. This issue is brought forward to people's attention and can be used for more detailed studies and research in coming days.

This study is based on the quantitative determination of microplastics leached from the plastic containers packed with mineral water and non-alcoholic beverages. Indian standard has specified various types of simulants and test conditions for various type of foods which is given in table 1 and 2. The choice of simulant depends upon the type of food products used, time-temperature condition and also depend upon the use of food products which is given in table 3. Bureau of Indian Standard IS 9845:1998 has classified the drinks and food products into seven categories. These drinks and foods have different simulants and test conditions, which is based on the pH and fat content of the drinks and food products which is given in table 2.

In the present study simulant A (distilled water) was used for mineral water and simulant B (3 % acetic acid) was used for non-alcoholic beverages. European Union (EU), Bureau of Indian Standard (BIS) set the limits for migration of microplastic for food and beverage products as 60 ppm or 60 mg/L. This is the upper limit for overall migration. If the migrating substance has color then that is not suitable for packaging drinks and foods even if the extractive value is below the limit [19].

Table 1: List of food simulants.

Simulant A	Distilled water
Simulant B	Acetic acid 3 %
Simulant C_1	Ethanol 10%
Simulant C_2	Ethanol 50 %
Simulant D	n-heptane
Simulant E	Mixture of synthetic triglycerides or sunflower oil or rectified olive oil

Table 2: Categories of drinks and foods with simulants.

S.N.	Type	Discriptions	Example	Simulant
1	1	3Aqueous non-acidic foods (pH>5) without fat	Honey, rasgulla, yeast paste and mineral water etc.	A
2	2	Aqueous acidic foods with no fat (pH≤5)	Fruit juices, carbonated beverages, lemonade, etc.	B
3	3	Alcoholic beverages: a. Concentration of alcohol less than 10 %	b. Concentration of alcohol above 10 % Beers, pharmaceutical syrups Whisky, Wine, brandy, etc.	C_1 C_2
4	4	Fats and processed dry foods with surface fat or volatile oil, oils	Vegetables, ghee, biscuits, chocolates, tea and coffee powder	D
5	5	Non-acidic foods (pH>5) with excess fat and excess moisture content	Butter, bread, pastry, milk-based sweets, ice-cream, etc.	A and D
6	6	Acidic foods (pH< 5) with excess fat and excess moisture content	Different types of pickles, tomato ketchup, cheese, mayonnaise, etc.	B and D
7	7	Dry processed foods having no fat	Different types of cereals, pulses, dry fruits, vegetables, salt, sugars, oats, etc.	No end test

Table 3: Simulants with time-temperature conditions.

S.N.	Conditions	Types of food and drinks	Time-temp of water	Time-temp of 3% acetic acid	Time-temp of 10 % alcohol	Time-temp of 50 % alcohol	Time-temp of n-heptane
1	High temperature heat sterilized	1, 2, 4	121 ^{0}C	2h 121 ^{0}C 2 h	-	-	66 ^{0}C for 2h
2	Hot filled or pasteurized above 66^{0}C, below 100 ^{0}C	1, 2, 4, 5 and 6	100 ^{0}C 2h	100 ^{0}C 2h	-	-	49 ^{0}C for half an hour
3	Pasteurized or hot filled below 66 ^{0}C	1 to 6	70 ^{0}C 2h	70 ^{0}C for 2h	70 ^{0}C for 2h	70 ^{0}C for 2h	38 ^{0}C for an hour
4	Filled and stored at room temp and also in refrigerated and frozen condition	1 to 6	40 ^{0}C for 10 days	40 ^{0}C for 10 days	40 ^{0}C for 10 days	40 ^{0}C for 10 days	38 ^{0}C for an hour

2 Methodology

Test Standard: The overall migration of various plastic containers were determined with IS 9845:1998 method.

2.1 Determination of conjugative weight of Beakers

It is very important for this research work to take the conjugative weight of the beakers into consideration. Hence, Fifteen beakers of 100 mL each were cleaned and were placed inside the oven with temperature 100 ^{0}C for 2h. Then the beakers were removed from the oven and placed in side the desiccator. After cooling inside the desiccator, weight of the beakers were measured. The process of cooling and weighing were repeated till the constant weight was determined. This process of conjugative weight determination was carried out for all the beakers.

2.2 Preparation of sample solution

Glacial acetic (3 mL) was placed in a volumatic flask and 97 mL purified water was added to form 100 mL 3 % acetic acid solution.

2.3 Sample selection

The Samples were randomly selected from different areas inside Kathmandu. Sample selection was done on the basis of their storage condition, type of products mostly used by children and teenagers, plastic condition and local manufacturing products. Three samples of same batch number were taken. 12 Mineral water bottles of four different brands and 12 bottles of non-alcoholic beverages from four different brands were also taken for the testing (two different brands of mango drinks and two different brands of litchi drinks).

2.4 Procedure

The plastic bottles used for the analysis were rinsed with distilled water for three times. The pH value of each sample was noted. After that, the plastic bottles were filled to their normal capacity with their respective simulant and the lids were closed. Sonication was carried out to avoid formation of bubbles. Consequently, the bottles were then placed inside the oven at specified temperature for required time. Then after, the plastic bottles were removed from the oven and content of each bottle was poured into the beaker. The bottle was rinsed with fresh simulant and then again poured into the same beaker.

In case of mineral water sample, three plastic bottles of four different brands were taken and their pH value was read then water from plastic bottle was removed. The plastic bottles were rinsed with distilled water three times. Then the bottles were filled with simulant A (distilled water) to their normal capacity and lids were closed. Sonication was carried out to avoid formation of bubbles. Then those filled bottles were placed inside the oven at temperature 40 ^{0}C for duration of 10 days. Then the water bottles were removed and the content of each bottle was poured into the beaker whose constant weight was already measured. The bottle was rinsed with fresh simulant and then again poured into the same beaker.

Similarly, in case of non-alcoholic beverages, same procedure was applied but simulant B (3 % acetic acid) was used as food simulant and the time and temperature condition were also same as in case of mineral water samples. Blank test was also carried out for all the samples.

2.5 Calculation of extractive amount

Beaker content was evaporated to dryness and the beaker was kept inside the oven at 100 ^{0}C to obtain absolute dryness. Then the beaker was removed from the oven and kept in the desiccator for half an hour. After the beaker was cooled, it's conjugative weight was noted as 0.1 mg. Amount of extract was calculated in ppm. Similarly, blank test was also done without the sample and this process was done for all other samples.

Extractive Amount (Ex) = M/V * 1000 ppm or mg/L

where, M = mass of extract in mg - value of blank test and V = total volume of simulant applied for each sample in mL

3 Results and Discussion

Overall migration of microplastics in mineral water and non- acholic beverages were carried out using food simulants A (distilled water) and B (3 % acetic). It was seen that every plastic packaging leaches the microplastic in different quantities depending on type of plastic container, storage temperature, storage duration, pH value of drink and type of drink packed in the container.

3.1 From water bottles

Distilled water was used as food simulant in the overall migration test for mineral water bottles. Amount of microplastic found in plastic bottles of mineral water is different for different brands. Table 4. shows the amount of extractive for different mineral water bottles. Microplastics abundance ranges from 0.38 ppm to 0.54 ppm. The migration of microplastics in mineral water are within the limit provided by EU.

Table 4: Overall migration in mineral water.

Sample No.	Simulant (mL)	Amount of Extractive triplicate (ppm)
1	1000	0.4466
2	1000	0.0333
3	1000	0.0666
4	1000	0.7100

Table 5: Overall migration in non-alcoholic beverages.

Sample No.	Simulant (mL)	Extractive (ppm)
1 (Lichee drink)	150	75.0560
2 (Lichee drink)	170	5.6399
3 (Mango drink)	250	0.4266
4 (Mango drink)	250	0.2933

3.2 From water bottles

3 % Acetic acid was used as food simulant for the non-alcoholic beverages. 12 samples of four different brands along with blank were studied for overall migration. Table 5. shows the amount of extractive for different non-alcoholic beverage bottles. The results show that among 12 samples of mango and lichee drinks only one sample of lichee drink (sample no. 1) exceeded the limit of migration of microplastics given by EU.

3.3 From water bottles

As the present study is based on the quantitative measurements only and depicts the preliminary analysis of microplastic migration based on plastic packaging of mineral water and non-alcoholic beverage that resulted in above mentioned findings. According to Oßmann et al., 2018, in blank samples, 384–468 microplastic particles per liter were discovered. Mineral water included anywhere between 2649 and 2857 microplastics per liter in single-use PET bottles, 4889 to 5432 microplastics per liter in multi-use PET bottles, and 6292 to 10,521 microplastics per liter in glass bottles whereas according to Shruti et al. (2020), microplastics in a range of sizes (0.1-3 mm) and hues, including blue, black, and brown, were discovered in non-alcoholic beverage such as soft drinks, energy drinks, and cold tea. Hence, end to end relative data is not available for comprehensive comparison.

4 Conclusion

The overall migration limit is 60 mg/L or mg/kg or ppm for plastic container used for food packaging as given by the EU. Present study showed that the migration in mineral water occurred in the range 0.38 ppm to 0.54 ppm. However, the migration limit was within the range specified by the EU. In case of non-alcoholic beverages, overall migration of microplastics exceeded the limit provided by EU in one sample only. This might be due to the type of plastic container, storage conditions, duration of storage and quality of the drink. However, the occurrence of microplastic leaching was evident which indicates that every plastic leaches which is an environmental and health risk. This shows that long term use of these kind of drinks affect the human health gradually and especially for children the risk is very high. The microplastics are consumed along with the food and drinks and after consumption it might disrupt the metabolic activities inside the body that can cause different types of diseases in the long run. Therefore, consumption of these kinds of foods and drinks packed in the plastic containers should be discouraged. Alternative solutions such as use of bio-degradable plastic containers, use of paper packaging and awareness on plastic leaching to general public should be conducted. To facilitate this, relevant policies should be implemented from local bodies and government entities. Moreover, traditional plastic packaging practice should be penalized and use of bio-degradable options should be promoted.

Acknowledgement

The authors would like to extend heartfelt gratitude to the University Grant Commission (UGC), Bhaktapur, Nepal for funding the research work under the Small Research Development and Innovation Grant (SRDIG) Award no. 76/77-S and T-8 and Zest Laboratories and Research Center, Balkot, Bhaktapur, Nepal for carrying out all the experiments for this research work.

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