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Article

Estimation of microplastics distribution in soil sample from District Una, Himachal Pradesh, India

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Abstract: Plastics have become an indispensable part of our daily lives. Its production and usage are increasing day by day. Our lives have become dependent on plastic-based products, and we are frequently exposed to plastics. The oxidation, fragmentation, and leaching stimulate the formation of small (1 µm–5000 µm) particles termed microplastics. The current study facilitates the assessment and quantification of MPs in soil samples collected from 5 sites (Amb, Gagret, Mubarikpur, Una city, and Tahliwal) in district Una, Himachal Pradesh, India. Soil samples were treated with NaCl for density separation and 30% H_2O_2 for digestion of organic matter. After sample treatment, the obtained supernatant was visualized under a stereomicroscope. In the current study, fragments (81.06%) were the dominant MP type identified, followed by fibers (16.04%) and films (2.89%). Similarly, MPs obtained were of various colours, such as purple (59%), greenish purple (5%), yellow (5%), blue (2%), green (1%) and transparent (28%). The highest microplastics concentration was detected in the soil sample from Tahliwal due to the disposal from small-scale industries and domestic waste, while the lowest microplastics concentration was detected in the soil sample from Una city. However, further research is needed to identify the polymer type and to check the possible source of microplastic examined.

Keywords: health; microplastic; polymers; soil; shape

1. Introduction

Since the creation of plastic in the early 19th century, its production and usage are increasing day by day. Plastics are extensively utilized in daily life and usually preferred in many areas, such as construction sites, textiles, households, offices, the medical field, kitchenware, toys, footwear, and packaging. Globally, the major portion of plastics is utilized for packing (30%), construction work (17%), and transportation (14%). Worldwide production of plastic has increased from 1.7 Mt in 1950 to about 350 Mt in 2021, and only 10% of it is recycled [1].

Plastics are classified in different categories on the basis of their chemical structures and nature (thermoplastic and thermosetting). Thermoplastics are softened plastics that can be deformed easily on heating, like polyethylene, PS, PP, PVC, and polycarbonate. While the thermosetting plastics are non-mouldable, such as epoxy resins, polyester resins, polyurethane, etc. Plastics are cheap, flexible, low-cost, have good moisture resistance, are economical, easy to process, and have electrical and thermal insulating properties [2]. Soil is the world's most abundant environment, the primary habitat for both known and unknown biodiversities [3]. Human life would be impossible without soil. Soil gives plants a place to put their roots and store the nutrients they need to flourish. It also filters rainfall, may store a high amount of organic carbon, and acts as a pollutant buffer.

Microplastics (MPs) can be found in the soil in forms such as primary microplastics, secondary microplastics, and larger plastics, which may be evident due to disposal of waste in soil, accumulation from various sources, and usage of plastic. With the passage of time and environmental actions, tons of plastic leftovers were found in the soil because of mulching procedures converted into MPs. The MPs that arise spread in the soil and interact with other pollutants like heavy metals, insecticides, and POPs, generating cumulative harmful effects on soil flora and fauna. Agricultural water runoff may eventually carry these MPs to rivers, oceans, and other water bodies [4,5]. Consequently, they reach the human body by following different routes from the soil, such as soil microorganisms (through food ingestion), air (construction materials, trash burning, artificial fibers from clothing, and aerosols like dust, fog, forest exudates, and geyser steam), and water (PVC pipes, fishing gear, and water filtering equipment's), etc. [6–8].

Globally, most of the studies reported the presence of MPs in marine water [9], rivers [10], drinking water, and freshwater [11]. Similarly, most of the research in India is limited to coastal areas, but reports addressing the presence of MPs within the soil are very limited [12–14]. MPs presence in soil are responsible for soil structure breakdown and have a negative impression on the water-retaining capacity of the soil [15]. Further, these microplastics can cause various health disorders like miscarriage, infertility, decreased sperm quantity and quality, chromosomal abnormalities in ovum (eggs), inflammations, toxicity, and respiratory and liver diseases in humans [16].

Our research endeavors to address the gap by undertaking a comprehensive study of prevalence, kinds, and distribution of MPs in the soil sample of Una district, Himachal Pradesh (India). Moreover, there is an absence of studies on MP distribution in this region. Our objective is to provide significant insights that are relevant to the local context through a quantitative and qualitative assessment. These insights will influence plans for the regulation and mitigation of MP pollution in this specific area.

2. Material and methods

Study Area: Soil samples (n = 6) were collected from each site of Una district, comprising urban, rural, and agricultural soil. Coordinates of sampling site included Amb (31.6856°, 76.1331°, 478 m), Gagret (31.6868°, 76.0732°, 439 m), Mubarikpur (31.7049°, 76.0949°, 478 m), Una (31.4451°, 76.2548°, 369 m), and Tahliwal (31.3491°, 76.2614°, 389 m) regions of Una district of Himachal Pradesh, India (**Figures 1** and **2**). A control sample was collected from the university campus (32.2253°, 76.1467°, 764 m) because of its regulated environment, minimal industrial influence, and established waste management procedures. Samples (1000 g) were collected as composite samples from four discrete sites of each sampling area targeting the top 30 cm of soil layer, which was combined and homogenized into a single sample. A stainless-steel shovel was used for sample collection and transported to the laboratory in aluminum foil paper. A control sample free from plastic was created by sieving manually and transferred to a hot air oven or ignited at 500 °C. The temperature attained guaranteed elimination of all plastic particles.

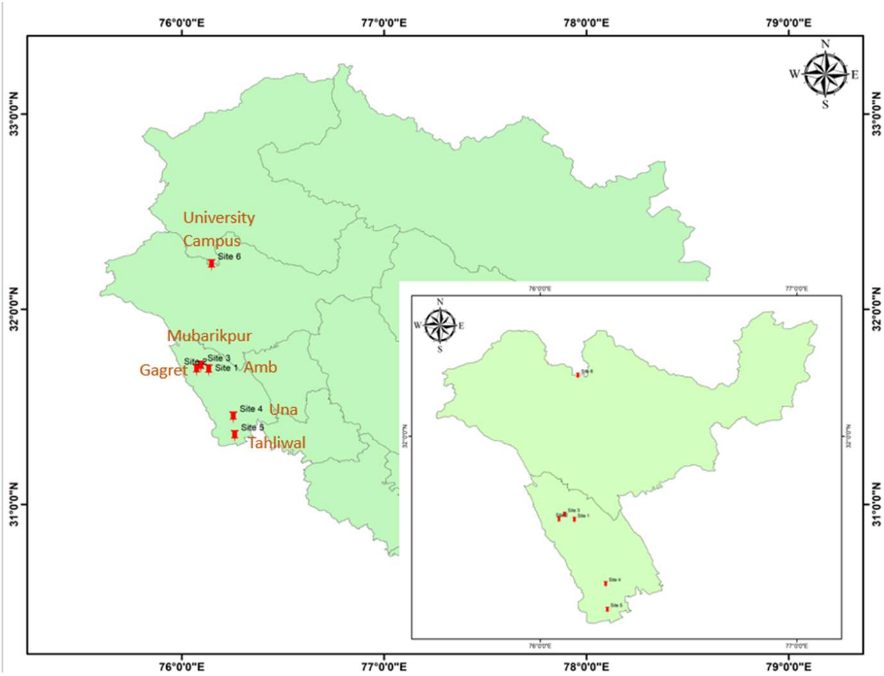

Figure 1. Map locating sampling sites in district Una.

Figure 2. Sampling sites: Urban: **(A)** (Amb), **(B)** (Gagret), Rural: **(C)** (Mubarikpur), **(D)** (Una), Agricultural: **(E)** (Tahliwal) and Control: **(F)** (University Campus).

3. Microplastics extraction

In the laboratory, homogenized and dried soil samples were sieved using stainless steel mesh of pore size 1 mm–5 mm. 50 g of soil sample in triplicates was taken. The density separation method was used for microplastics detection [17]. Distilled water (20 mL) was added to the soil sample (50 g). The soil sample was mixed with 20 mL of saturated NaCl (5 M) solution in a glass beaker. A stir bar was added to the solution, and the solution was continuously stirred at 2200 rpm for 10 minutes. After that, 20 mL of $ZnCl_2$ (5 M) was added to the solution, and the solution was stirred at 2200 rpm for 15 minutes using a magnetic stirrer. The solution was allowed to settle down for 2 hours. The solution was then filtered carefully using Whatman CAT No. 42 (pore size 2.5 μm) filter paper, and the filtrate was collected in a new beaker.

3.1. Removal of the organic matter

Microplastics were separated from organic matter, which is typically present in agricultural soil. Soil organic matter has a density of $\rho < 1.6$ g·cm^{-3} [18], which is similar to that of microplastics $\rho = 0.9$–1.6 g·cm^{-3} [19] and cannot be completely removed by the density separation.

The organic matter present in the filtrate obtained in the previous step was removed by oxidizing the sample using 30% H_2O_2 at 65 °C for 24 h [20]. The digested sample was again filtered with the Whatman CAT No. 42 filter paper, followed by direct observation of the filter paper under the stereomicroscope.

3.2. Microplastics analysis

Visual evaluation was performed to identify the MPs according to the physical characteristics (shape and color) of the particles. The filtered sample were then visualized under stereomicroscope (Magnus CH201) at 10X and 40X magnifications [21].

3.3. Quantitation of MPs

For quantitative estimation of microplastics, the calculation formula was applied in order to check the concentrations of MPs contamination per kg of sample [22].

$$MP_{corr} = (MP_{vis} \times P_{error})/W$$

where, MP_{corr} = Average contamination of MPs per Kg of soil sample.

MP_{vis} = No. of visually identified particles/sample under stereomicroscope.

P_{error} = Theoretical error value (significant value of $P_{error} \leq 0.05$)

W = Weight of sample taken i.e., 50 g.

3.4. Quality control and assurance

Prior to each step, all glasswares and containers were given a three-time cleaning in distilled water, after which they were sealed in aluminum foil. Plastic instruments were avoided throughout the experiment to prevent plastic contamination of the samples. During the entire operation, nitrile gloves and cotton lab coats were worn. The area for stereomicroscopic inspection was meticulously cleansed before the analyses of the sample to avoid any potential contamination.

3.5. Statistical analysis

A t-test was used to compare the difference in the average number of microplastics in the soil samples.

4. Results and discussion

The present study was conducted in five different sites in district Una, Himachal

Pradesh. Five different sites were Amb, Gagret, Mubarikpur, Una, and Tahliwal. Soil samples collected revealed site-specific varied abundance (**Figure 3**). The control sample confirmed the absence of the microplastic contamination through the medium used. Microplastics were counted visually and were categorized into various categories, typically based on their colour and shapes. The microplastics obtained were of various colors, such as green (1%), yellow (5%), blue (2%), purple (59%), and transparent (28%) (**Figure 4**). Concordantly, Feng et al. [23] also found transparent and colourless (49.02%) microplastic dominating in grassland and farmland soil in Tibet.

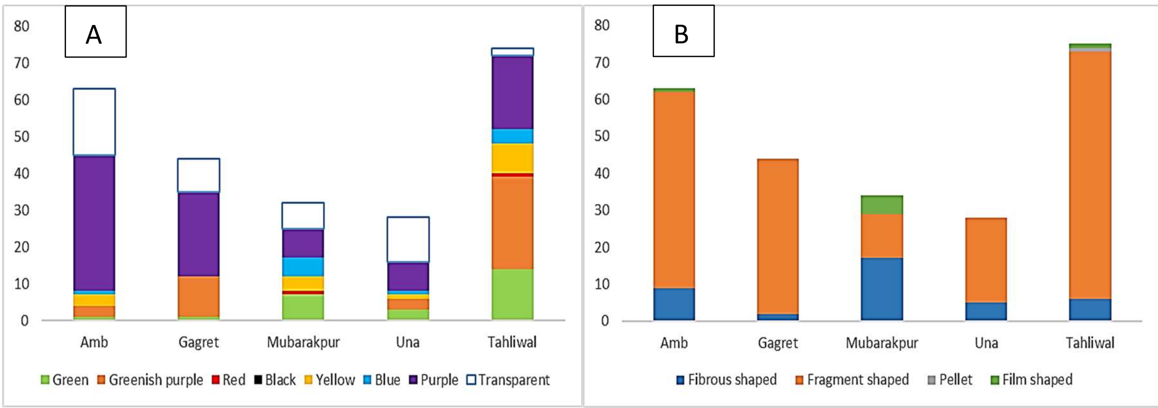

Figure 3. Distribution of microplastics examined in the study sites based on **(A)** Color and **(B)** Shape.

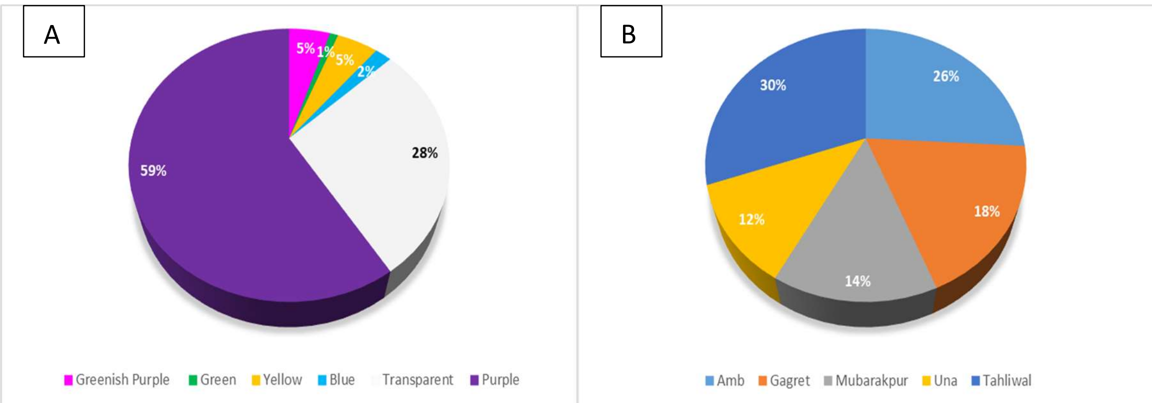

Figure 4. Percentage based **(A)** Color, **(B)** Shape distribution of microplastic in the Una district, Himachal Pradesh.

Similarly, the shape-based microplastics identified were fragmented, fibrous, film, and pellet-shaped. The abundance of MPs identified varied about 81.06% as fragments, followed by fibers (16.04%) and films (2.89%). Zhang and Liu [24] reported 92% fibers, followed by fragments and films (8%) in the soil aggregate fraction in South Western China. In contrast, Karthik et al. [25] reported fragments (50%) in abundance rather than fibers (27%) and foam (19%) in the soil sample. Whereas the present study found fragments to be the most dominant shape, which indicates that the larger fragments of plastic might have broken down into smaller fragments due to various chemical, physical, and biological factors [26]. The study by Lehtiniemi et al. [27] suggested fibers shape as a secondary source of microplastic. The abundance of fibers has been reported in other areas such as Xijin Wetland Park, Nanning, South China [28], Dongting Lake, and Hong Lake, China [29].

Since microplastics size ranges from 1 µm–5 mm [30], the size of microplastic examined varied from 0.44 µm–69 µm (**Figure 5**). The smallest fragment of MP examined was of length 0.44 µm, which was light blue in colour, and the longest particle was of size 69 µm, which was fiber in shape (**Figure 5**). A previous study has reported an almost similar particle size range of 0.1 mm to 2 mm from the sediment samples [31]. In contrast to Chen et al. [32], who reported MPs of size ranging from 3 µm–50 µm in samples.

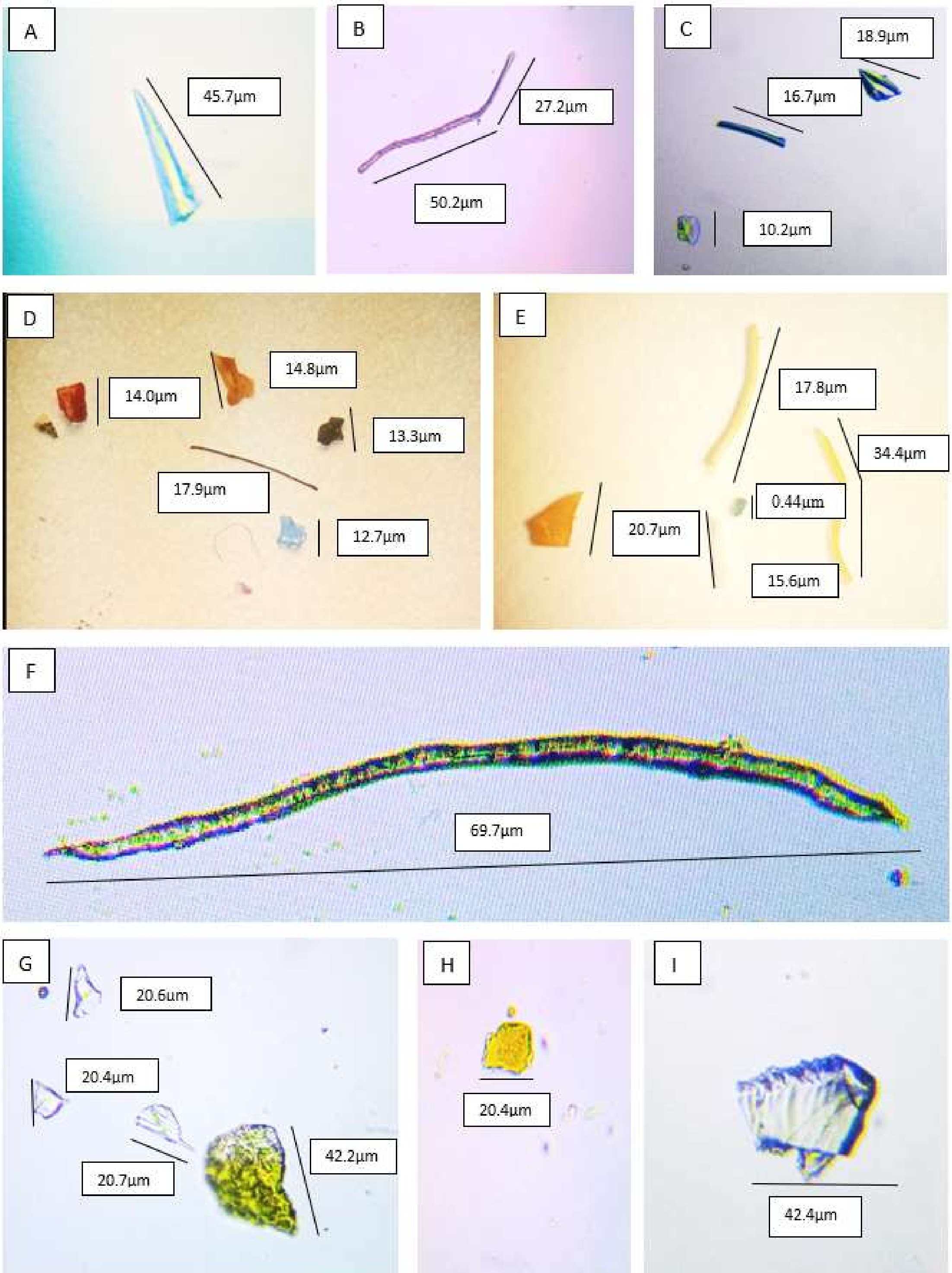

Figure 5. MPs observed in the soil samples **(A, C, D, F, G, H)** (Fragments), **(B** and **E)** (Fibers).

The average concentration of microplastics in diverse sampling sites situated in Distt. Una was 0.021 particles/150 g (Amb) and 0.014 particles/150 g (Gagret) comprising of urban location, while 0.011 particles/150 g (Mubarikpur) and 0.009 particles/150 g (Una) in rural area and 0.024 particles/150 g (Tahliwal) in agricultural land. Significantly higher MPs concentration was observed in all sites except Una and Mubarikpur. A soil sample collected from sampling site 5 (Tahliwal, agricultural land) was reported to be highly contaminated with MPs, which may be accredited to the composition of microplastics in pesticide packaging, regular mulching containing plastic, and environmental deposition [33,34]. The reasons behind rising MPs pollution in this city are industrial effluents, household garbage, and waste dumping in soil. Soil contamination with microplastics alters the physical properties of soil, such as aeration, porosity, and water holding capacity, and affects the microbial community [35,36].

Plastics are complexed materials made up of more than 10,000 chemical components like additives, colorants, dyes, luster additives, processing aids, resins, and other compounds that are used to enhance the rigidity and flexibility of the plastic products, which are known to be toxic to both human health and the atmosphere [29,37,38]. Ingestion and inhalation are two key routes of exposure to plastic additives that may enter the gastrointestinal tract or lungs [39].

5. Conclusion

The smaller the size of plastic, the higher the level of damage. The main reason behind rising MPs pollution in this city is industrial effluents, household garbage, and waste dumping in soil. Considering the negative impact of the contamination, there is a need to create awareness of the consequences of microplastic presence. Even though the government and policymakers have passed several rules and regulations, it is the responsibility of individuals and organizations to guarantee that the policies are followed to preserve ecosystems from the harmful impacts of plastic litter.

Author contributions: Conceptualization, RS; methodology, SD; validation, RS; formal analysis, SD and DS; investigation, SD; data curation, RS; writing—original draft preparation, SD; writing—review and editing, RS and DS; visualization, SD and NK; supervision, RS. All authors have read and agreed to the published version of the manuscript.

Conflict of interest: The authors declare no conflict of interest.

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