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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 size (1 µm–5000 µm) particles termed as microplastics. The current study facilitates the assessment and quantification of MPs in soil sample 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, obtained supernatant were visualized under stereomicroscope. In the current study, fragments (81.06%) were the dominant MPs 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 soil sample from Tahliwal due to the disposal from small scale industries and domestic waste while the lowest microplastics concentration was detected in 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 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 in construction sites, textile, households, offices, medical field, kitchenware, toys, footwear, and packaging. Globally, the major portion of plastics are 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 bases of their chemical structures and nature (thermoplastic and thermosetting). Thermoplastics are softened plastics which 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, good moisture resistance, economical, easy to process and with electrical and thermal insulating properties [2]. Soil is the world's most abundant environment, the primary habitat for both known and unknown bio diversities [3]. Human life would be impossible without soil. Soil gives plant a place to put their roots and store the nutrients they need to flourish. It also filters rainfall and 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 found in the soil because of mulching procedures converted into MPs. The MPs that arise spread in the soil and interact with other pollutant 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 gears 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 researches in India are 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 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, 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 are absence of studies on MPs distribution in this region. Our objective is to provide significant insights that are relevant to 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 ditrsict comprising of 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) region of Una district of Himachal Pradesh, India (**Figures 1** and **2**). Control sample was collected from 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 sample from four discrete sites of each sampling area targeting top 30 cm of soil layer, which was combined and homogenized into single sample. A stainless-steel shovel was used for sample collection and transported to laboratory in aluminum foil paper. A control sample free from plastic was created by sieving manually and transferred to hot air oven or ignited at 500 ℃ temperature. The temperature attained guaranteed elimination of all plastic particles.

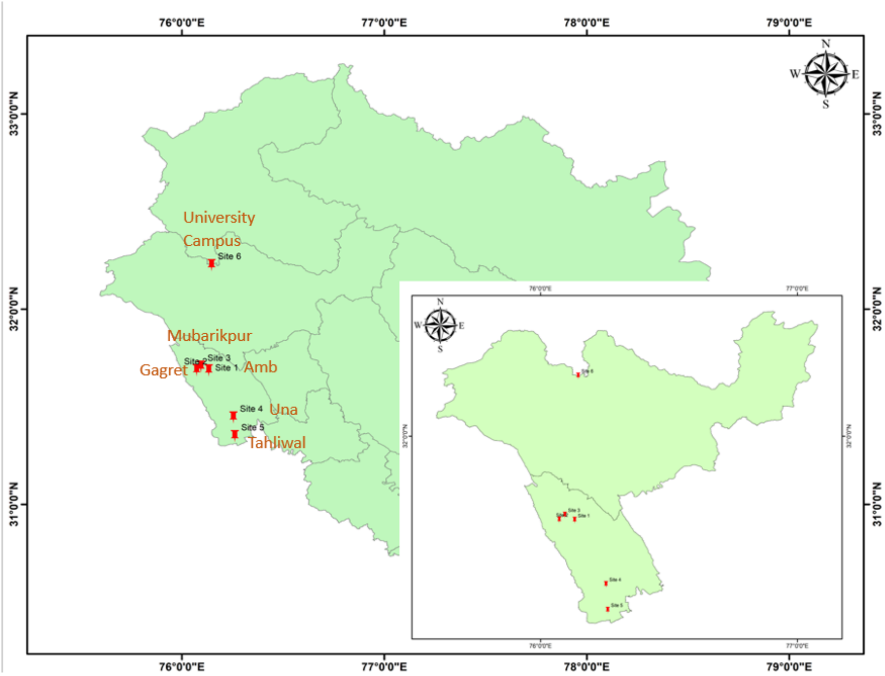

Figure 1. Map locating sampling sites in district Una.

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 laboratory, homogenized and dried soil sample was sieved using stainless steel mesh of pore size, 1 mm–5 mm. 50 g of soil sample in triplicates was taken. Density separation method was used for microplastics detection [17]. Distilled water (20 mL) was added to the soil sample (50 g). Soil sample was mixed with 20 mL 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 $ZnCl_2$ (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 new beaker.

3.1. Removal of the organic matter

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

The organic matter present in filtrate obtained in 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 glass wares and containers were given a through 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

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

4. Results and discussion

Present study was conducted in five different sites of district Una, Himachal Pradesh. Five different sites were Amb, Gagret, Mubarikpur, Una, and Tahliwal. Soil samples collected revealed site specific varied abundance (**Figure 3**). Control sample confirmed absence of the microplastic contamination through 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.

Similarly, shape based microplastics identified were fragmented, fibrous, film and pellet shaped. 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 soil aggregate fraction in South Western China. In contrast to Karthik et al. [25] reported fragments (50%) in abundance than fibers (27%) and foam (19%) in soil sample. Whereas, in the present study found fragments to be the most dominating shape which indicate 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] and Dongting lake and Hong lake, China [29].

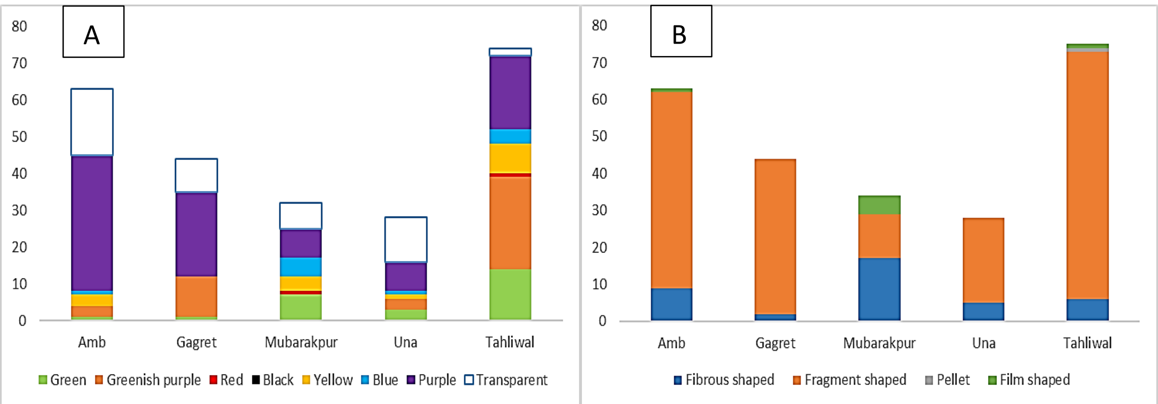

Figure 3. Distribution of microplastics examined in the study sites based on **(A)** Color and **(B)** Shape.

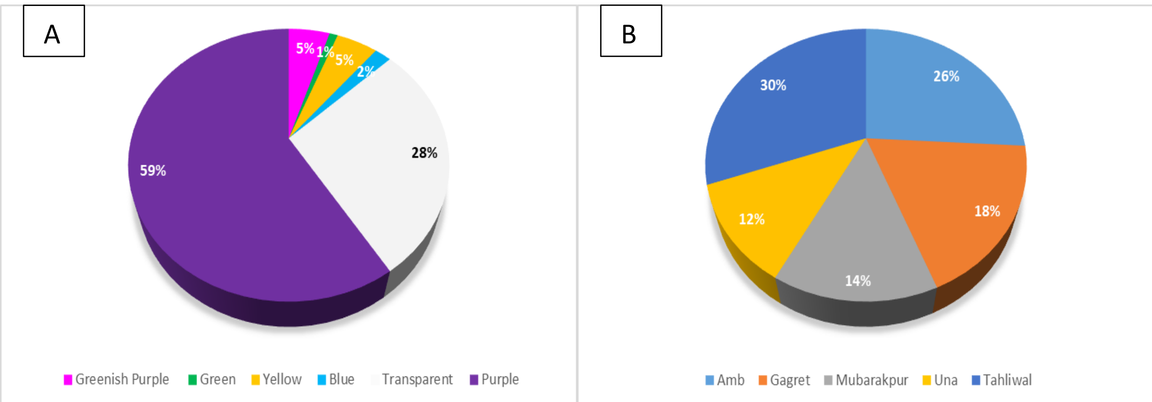

Figure 4. Percentage based **(A)** Color, **(B)** Shape distribution of microplastic in the Una district, Himachal Pradesh.

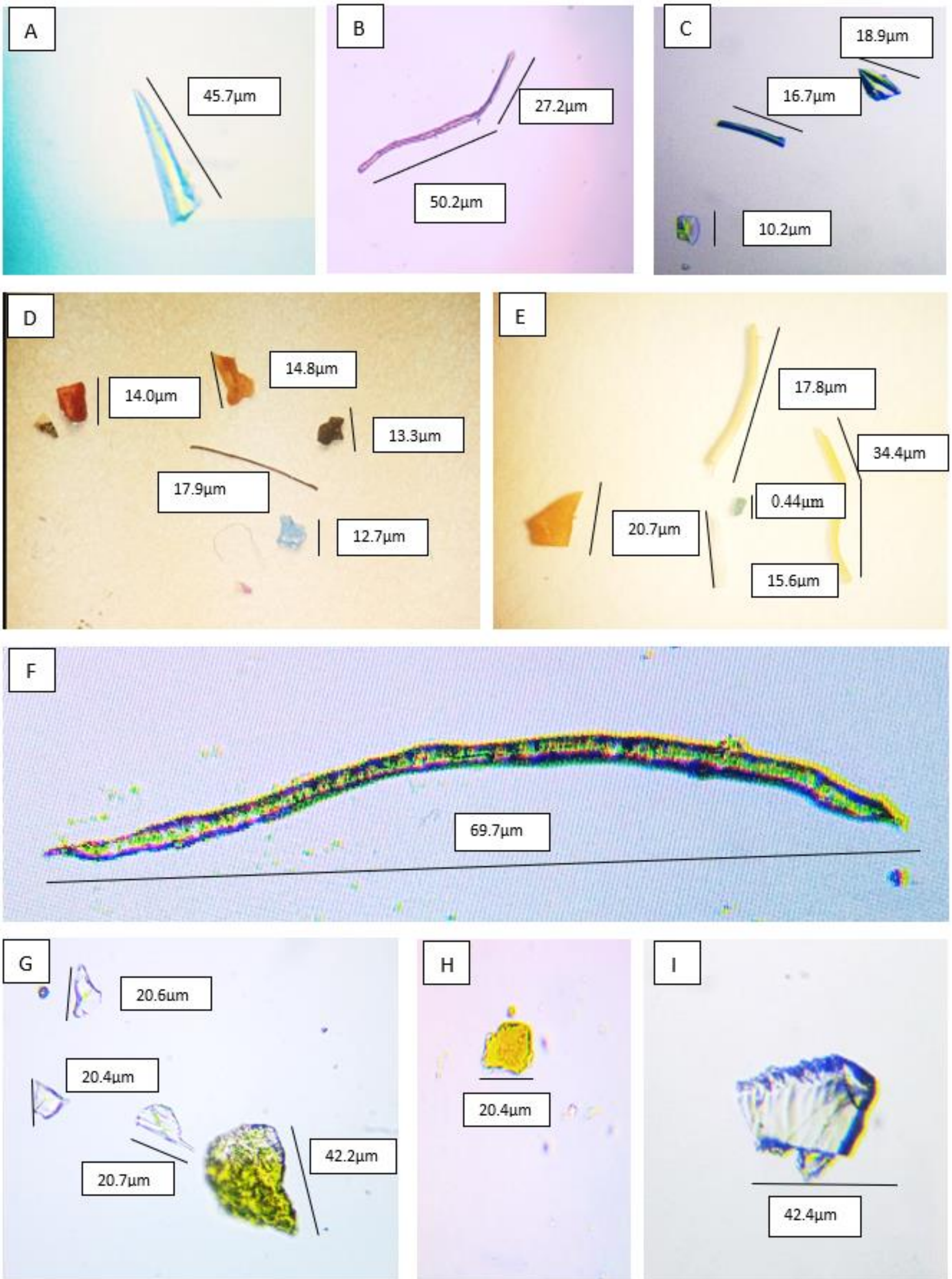

Figure 5. MPs observed in the soil samples **(A, C, D, F, G, H)** (Fragments), **(B** and **E)** (Fibers).

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 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.

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. 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 pesticides packaging, regular mulching containing plastic, and environmental deposition [33,34]. The reasons behind rising MPs pollution in this city is industrial effluents, household garbage and waste dumping in soil. Soil contamination with microplastic alter the physical properties of soil, such as aeration, porosity, water holding capacity, and affect microbial community [35,36].

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

5. Conclusion

Smaller the size of plastic, 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 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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