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Review

A Perspective on Plastics and Microplastics Contamination in Garden Soil in British Columbia, Canada

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Abstract: Plastic contamination is commonly reported in urban and rural soils, as well as in fresh and ocean waters. Canada's government has attempted to limit the contamination of single-use plastic by banning the manufacturing and selling of specific types of plastic. In British Columbia, current regulations governing commercial composting state that when compost has less than 1% of its dry weight representing foreign materials (including plastic), it can be sold and used in soils. However, due to the low density of plastic and its potential to break down into microparticles, this amount may be enough to become toxic when used in agricultural soils. This paper studies contamination of plastic in garden soils and summarizes how this can affect the environment with a preliminary examination of a garden soil sample. The examination showed that the garden soil sample contained mainly low-density polyethylene, polyethylene and polypropylene plastics (identified through ATR-FTIR) in oxidized and unoxidized forms that can come from commercial composting and hypothesizes that this plastic could break down into microplastic particles. In order to limit the amount of plastic contamination in agricultural soils, it is necessary to modify current compost regulations in order to treat plastic differently than other foreign materials (glass, metal, wood).

Keywords: plastic contamination; microplastic; garden soil; Canada legislation

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1. Introduction

In recent years, there has been an exponential growth in the consumption of plastics. Facts illustrating this reality are easy to find in the data on the global consumption of plastics, which increased from 460 thousand tons in 2019 to 490 thousand tons in 2023 [1]. Over the last 50 years, the increase in annual plastic production has grown by 20% [2]. Plastics are considered pollutants because they have large molecular weights, chemical stability, they contain toxic compounds, and they are petroleum derivative products. Although the degradation time of plastics is widely debated, it is believed that the half-life degradation of high-density polyethylene (HDPE) in the marine environment, for example, is an average of 58 years for bottles and 1200 years for pipes. However, some researchers believe that plastic never fully degrades [3]. Due to its persistence and slow decomposition rates, this material accumulates in large quantities in the environment, and unfortunately, only 9% of plastic is recycled, while 12% is incinerated, and the remainder of it is disposed of in landfills or disposed of inappropriately into the environment [4].

Data on plastic contamination have been reported in different parts of the world; however, in the soil of agricultural farms in Europe and North America alone, it is estimated that there are 63,000–430,000 microplastic particles (MPs) in micrometric sizes [3].

The literature establishes that MPs are any small and irregular particles with polymeric matrices. Regarding size, MPs can also be categorized into small MPs, with a diameter between 1 µm and 500 µm, or large MPs with a 500 µm–5 mm diameter [5]. Some researchers also classified the particles higher in mesoplastic (ME) and macroplastic (MA) particles that have diameters of 5 mm–2 cm, and larger than 25 mm, respectively [6,7].

Currently, despite much discussion about the presence of tons of plastic in the oceans and the severity of this problem, plastic contamination in terrestrial environments has been found to be as high as 23 times greater than in water [8]. For example, in the Bohai Sea estuary, an average of 510 plastic particles per kg were found in the soil, while in the ocean, this number was 163.5 particles per kg. It is suspected that there is also a significant flow of plastics originating from terrestrial environments and transported via water flow into the oceans. The problem of this type of contamination has been shown in various studies by the presence of MP in plants and animals, as well as in small organisms [9]. Li et al. (2018) collected oysters at 11 different sites in the Pearl River, China, and identified MP in all of them. These MP particles were ranging between 20 and 5000 µm in size [10] It has been reported in the literature that plastics in micro- and nano-sized particles have greater mobility in the food chain, hence requiring greater attention [2]. With this in mind, there is an urgency to understand how this contamination affects the natural environment and how problematic it can become for society if not properly controlled.

In 2020, the Canadian government began to impose measures to restrict single-use bags, straws, and packaging made of plastic material. The federal government plans to adopt public policies to eliminate plastic waste through the Single-use Plastics Prohibition Regulation (SUPPR). In British Columbia, organic municipal waste is collected separately from other waste and is sent to composting facilities. Compost is then prepared for sale and is subsequently placed on arable land or in residential gardens. The companies that carry out composting comply with regulations that impose a 1% restriction on foreign matter content in the compost. The maximum amount imposed could be any contaminants such as plastic, glass, metal, and paper, and no discrimination is made between these materials and plastics or MPs in composting. This regulation does not require that plastic be differentiated from other contaminants; therefore, there is also no guidance on the chemical analysis used for the identification of plastic as well as the quantification methods for plastics [11]. In addition, there are also ongoing academic debates regarding the exposure of humans to plastics and the assessment of harmful effects to human health. The effect of plastic concentration on living organisms is poorly understood, and there are disparities in the literature [9].

It has been reported that the most common types of plastics found in agricultural soils are low-density polyethylene (LDPE), polyvinyl chloride (PVC), ethylene vinyl acetate (EVA), and linear LDPE (LLDPE). These plastics can present various levels of toxicity depending on their particle size and concentration. Exposure to climatic conditions leading to their degradation can result in the production of transient products that can become even more toxic to living organisms and can have much greater mobility. Bioaccumulation of plastics allows plastic to reach levels in the food chain that can be harmful to other organisms.

In a study conducted in Australia, a garden sample was collected, and the presence of polyethylene (PE), polypropylene (PP) and bubble wrap were identified. MPs, MEs, and Mas ranging in size from 0.75 mm to 100 mm were identified, and it was pointed out that these samples could eventually degrade into nanoplastics (NP), thus highlighting the need to avoid undue disposal of MP in garden soils [12].

Farmland soils contaminated with different sizes of plastic were also registered in Shangay suburbs: an abundance of 62.50–78.00 items of MP per kg and 3.25–6.75 items of ME per kg. The area is known to have a large use of mulching practice that consists of covering agricultural soils with plastic films to preserve the humidity, heat, and fertilizer of the land. A difference was observed in the abundance of MP and ME according to the depth in the soil; 59.81% of the MP was concentrated in deep soil, showing the mobility of the particles [6]. Mulching is common in different parts of the world, achieving the consumption of 63,000 tons of plastic in Europe, and 44,000 tons in North America. The practice of composting is another source of plastic contamination in agricultural and horticulture soils. Based on results from commercial composting, it was seen that the utilization of 7–34 tons of composting generates 0.34–47.53 kg per ha per year in agriculture, while horticulture results in 0.31–26.4 kg per ha per year.

However, studies have also demonstrated a correlation between higher levels of PMs in urban gardens and plantations that are close to highways [13]. This relationship can be observed in a study carried out on different lettuces that were grown in urban and rural areas. While lettuces planted in rural areas had levels between 10 and 20 items of plastic per gram of lettuce, those grown in urban gardens had between 15 and 30 items of plastic per gram of lettuce [14]. It was also observed in Taiwan that soils from plantations close to highways have around three times more MPs than soils further away. With this, it is evident that the friction between car wheels and roads is an abundant source of PMs that are transported through the atmosphere [15].

As a result, urban regions are major emitters of plastic fragments. In the Greater Paris region, it was detected that there is a presence of MPs not only in gardens, but also in the total atmospheric fallout, in wastewater (untread and treated), and in the River Seine [16].

The sampling, separation, quantification, and identification processes of MPs are not yet completely established in the literature for either liquid or solid samples. While MAs are more easily detectable and quantifiable, MP or NP particles demonstrate difficulties and could reproduce results that may be underestimated [17–20]. According to Möller et al. (2020) [5], sampling methods for soil samples can be carried out on a sample that is identified visually as contaminated, or out of several random or equally spaced collections on a given site. Techniques such as simple manual and visual collection and sieving for MA are used to separate particles from soil matrices. On the other hand, in general, for the separation of ME and MP, concepts of hydrophobicity and density are used, based on plastics being low-density and hydrophobic materials [21]. With this, flotation, froth flotation, and density separations are used as solid/solid and solid/liquid separation methods. Additionally, magnetic and electrostatic methods are also used [17]. Due to interferences that organics matrices could promote in separations, a pre-treatment of digestion is made in heterogeneous and complex soil samples, in this case, a digestion acid or basic, and with oxidizing agents such as H_2O_2, Fenton reagent, HNO_3, KOH, NaOH, HCl, and $HClO_4$ [22]. In density separation, dense solutions are employed, and some examples include the utilization of reactants such as NaCl, KCl, $ZnCl_2$, NaI, and deionized water [23]. Filtration is used to promote the solid separation in the final steps. The separation of NP has been investigated by the literature, which is not completely consistent in standardizing the methods. Some techniques have been developed such as separation by magnetic field fractionation (MFFF), gel electrophoresis, and size exclusion chromatography (SEC) [24,25].

Fourier Transform Infrared (FTIR) and Raman spectroscopy are the most used techniques to identify MA and MPs because they are fast and non-destructive. For MPs, the use of micro-FTIR is recommended due to its higher spatial resolution [26,27]. Gas chromatography with mass spectroscopy (GC-MS) is also common. Due to the complex matrices containing non-completely digested organic contents, GC-MS pyrolysis is receiving attention from researchers. However, the main disadvantage of the chromatography technique is that it is expensive and destructive to the sample [20,28,29].

In order to investigate the appropriate methodology for the qualification and quantification of plastics in garden soil, a soil sample was collected from a residential community garden. The plastics found were isolated using physical separation methods, and they were characterized using infrared spectroscopy (FTIR). Current legislation and regulations practiced in British Columbia and Canada are discussed as they contribute to plastic contamination in soil wastes. A review of current science was completed, discussing plastic toxicity, degradation, and interactions that plastic can have with the environment.

2. Materials and Methods

The present article is a discussion that uses a sample from a garden as a basis to create a discussion on plastic contamination in solid wastes or composting in Canada. Thus, it used a methodology that is a blend of a preliminary sample study and a literature review. Canadian legislation and British Columbia composting regulations were reviewed to determine how plastic particles can find their way into community garden soils.

The study area was an urban community garden in a municipality located in British Columbia. A soil sample was collected from a garden plot that had recently been filled with garden soil that was delivered to the site for distribution between individual garden lots. One sample was selected for preliminary investigation to test how to identify plastic within garden soil. Considering that it was a sample from a community garden, it was not possible to know which the soil in question was and how it was composted. An aleatory sample was located and dug from a hole 0.16 × 0.16 × 0.16 m. The collected sample was homogenized, and the visible plastics were separated by sieving, using an industrial set of screens. The sizes and shapes of plastics were measured using optical microscopy with the use of ImageJ® 1.54d software. In addition, the identification of plastic types was performed by micro-FTIR-ATR (FTIR system connected to the optical microscope), model Thermo Scientific Nicolet iS50 FT-IR Spectrophotometer. To promote the analyses, the isolated plastics were cleaned and analyzed with the ATR accessory, and the spectrum was identified with the Hummel Polymer Sample Library through a comparison with the standard spectrums. The measurements of the size of the plastic particles were carried out considering that the shape of each one is a square, and from that, the circle diameter was calculated.

This paper also deliberates on regulations regarding plastics concentration in commercial compost which is used to make garden soils in British Columbia. A literature review on the biodegradation of plastics in garden soils and their toxicity effects on human health are also summarized.

3. Results

The soil collected from an urban community garden was "man-made" in such a way that it contained a mixture of compost, silt, sand, and woody debris. The plastic contamination was quickly noticed by gardeners as the colors varied from pink, red, green, blue, and white, and particles and were easily seen. Figure 1 shows plastic particles visible on the surface of two garden plots.

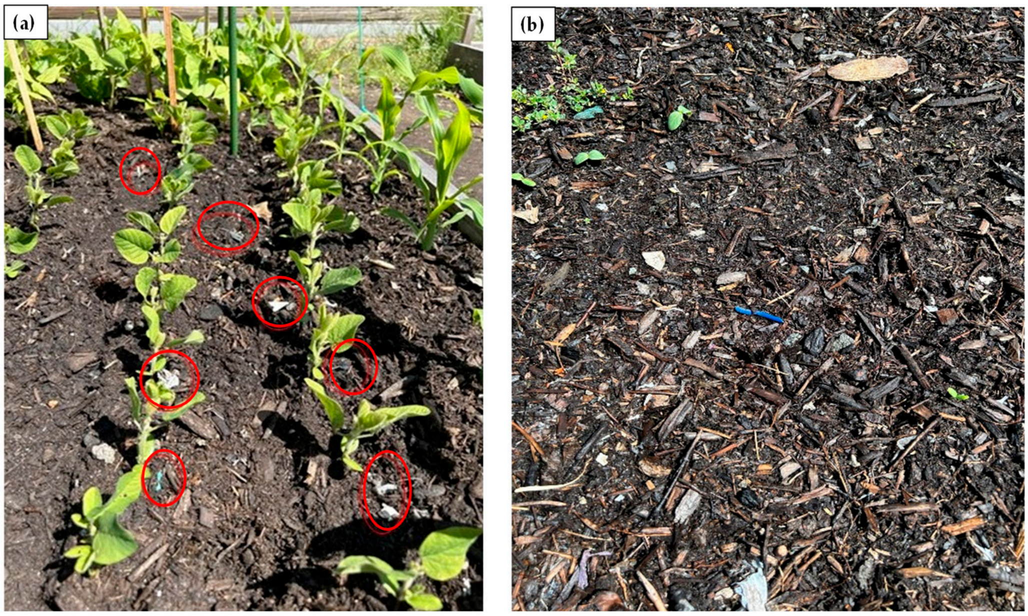

Figure 1. Garden soil (**a**) white plastic particles are noticeable on the surface of the garden, and (**b**) blue plastic particle visible along top of garden.

Figure 2 shows several plastic pieces collected from the surface of a garden plot in 5 min. These pieces were lightweight and would have certainly passed the concentration of the "less than or equal to 1% dry weight" restriction for foreign materials in the quality test for compost.

Figure 2. Pieces of plastic collected from the garden.

A 4-litre soil sample was collected from one of the garden plots. The sample location was chosen randomly. The soil was dried, and plastic pieces were removed after they were placed on the sieves. The plastics present in the studied garden soil are shown in Figure 3.

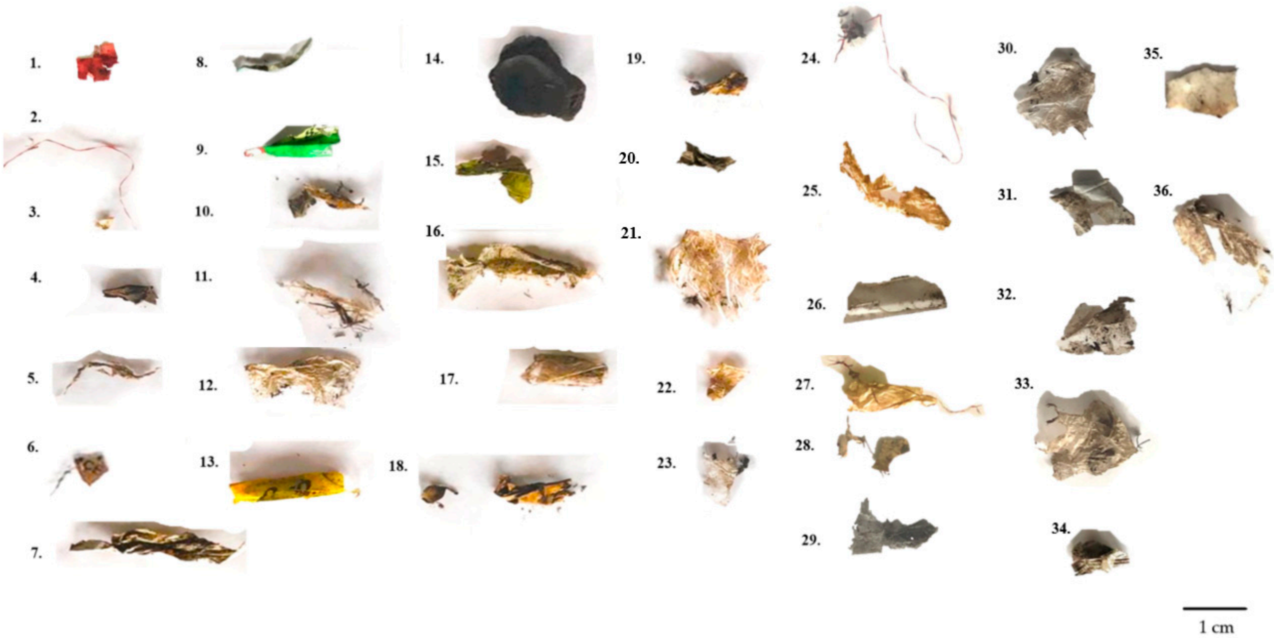

Figure 3. Plastic pieces collected from soil.

It was observed that the plastic pieces were varied in shape and color, some showed a fibrous habit (plastic numbers 3 and 23), and others were visually similar to the plastic used to make residential garbage bags, fruit bags, pieces of pen, and adhesive tape. For most of the particles, it was possible to identify their origin based on visual identification, for example, the plastic bags (plastics number 9, 13, and 21) and materials in some degree of decomposition (numbers 11, 12, 27, 29, and 35).

The transport and decomposition of plastic particles can vary based on shape, color, density, and other characteristics. Plastic particles similar to spheres tend to remain on the surface of soils, while fibrous and sharp-ended geometry is retained underwater. Low-density plastics could easily travel through air, crossing long distances and achieving different areas such as ocean, rivers, and plantations areas [30]. However, it is known that plastic materials found in the oceans were also found in soils in less advanced stages of decomposition, demonstrating the migration of these particles. In a recent survey, conducted in the United Kingdom, MPs were found in the Thames River basin; however, it was observed that the particles came from thermoplastic paints and derivatives that are used for marking roads, as well as bottle fragments, fabric fibers, made with PP, polystyrene, and polyamide (PA). With this, knowledge of the origin and trajectory that these MPs travel is important, as remediation measures should be taken so that contamination does not harm the environment and population [31].

The origin and transport of plastics and MP are not completely understood by researchers; in this way, the format, color, and composition are important variables to record. It is known that up to 15% of microplastic contamination can originate from composting [30,32]. A study showed that in Switzerland, 163 thousand tons per year of composting is destined for agriculture, and 78 thousand tons per year is destined for horticulture and landscaping; from these amounts, 47.6 tons is plastics [32].

Observing the compounds present in the sample is a way of helping to characterize the plastics found. To confirm the collected plastics from the garden sample, the similarity index given by FT IR was also used (Table 1). This number will give a value ranging from 0 to 100 comparing the similarity of the analyzed sample with a standard sample registered in the equipment's internal library. However, it is important to understand that in various cases, the similarity will not represent reality due to several factors, for example, the plastic sample is at some level of degradation with the disappearance of some bands in the spectrum. In Figure 4 are the spectrums of plastics 2 and 8, which were identified as PE and PP, but the literature indicates that PE has main bands in 2919 cm^{-1} (CH_2 asymmetric stretching), 2851 cm^{-1} (symmetric stretching), and 1473 cm^{-1} with 1463 cm^{-1}. Figure 4a presents an additional peak in 3340 cm^{-1} and 1629 cm^{-1}, which can be related to a bio-oxidized form of PE and the formation of carbonyl groups [33,34]. In the case of PP, some peaks formed also do not belong to the pure compound. According to Zhang et al. (2012) [35], PP does not have characteristic peaks in the regions of 1740 cm^{-1}, 1303 cm^{-1}, 1255 cm^{-1}, and 899 cm^{-1} which are present in the spectrum presented in Figure 4b. Furthermore, it is also possible to observe slight absorption in the region of 3400 cm^{-1}, which together with the peak of 1740 cm^{-1}, is characteristic of the oxidized PP. These peaks indicate a formation of polar structures and steric groups such as carbonyl, aldehyde, and anhydride [36].

Table 1. Identification and measures of the plastics found.

N°	Diameter (mm^2)	Roundness	Identification	Similarity (%)
1	14.35	0.52	Linear low-density polyethylene (LDPE)	45.07
2	13.99	0.05	Oxidized polyethylene (PE)	82.64
3	4.24	0.56	Polyamide 6 + Polyamide 6.6 (Nylon 6 and 66)	68.89
4	12.21	0.55	Oxidized polyethylene (PE)	88.50
5	11.91	0.23	Poly(ethylene-propylene-diene) (EPDM)	77.40
6	7.51	0.33	Acrylonitrile butadiene styrene (ABS)	52.14
7	21.26	0.31	Oxidized polyethylene (PE)	88.50
8	14.42	0.18	Poly(propylene) (PP), atactic	95.62
9	22.53	0.47	Poly(propylene) (PP), atactic	95.62
10	20.45	0.39	Poly(ethylene-propylene-diene) (EPDM)	77.40
11	20.50	0.26	Poly(ethylene-propylene-diene) (EPDM)	77.40
12	23.94	0.45	Poly(ethylene-propylene-diene) (EPDM)	77.40
13	19.98	0.41	Poly(propylene) (PP), atactic	95.62
14	23.34	0.84	Unkonwn	-
15	17.69	0.41	Polyamide 6 + Polyamide 6.6	73.23
16	29.96	0.24	Poly(ethylene-propylene-diene) (EPDM)	77.40
17	18.75	0.76	Poly(ethylene-propylene-diene) (EPDM)	77.40
18	17.69	0.46	Oxidized polyethylene (PE)	88.50

Table 1. *Cont.*

N°	Diameter (mm^2)	Roundness	Identification	Similarity (%)
19	13.39	0.53	Oxidized polyethylene (PE)	88.50
20	35.51	0.26	Oxidized polyethylene (PE)	88.50
21	13.05	0.65	Poly(propylene)(PP), atactic	95.62
22	17.71	0.70	Poly(ethylene-propylene-diene) (EPDM)	77.40
23	19.66	0.33	Oxidized polyethylene (PE)	82.64
24	16.73	0.55	Poly(ethylene-propylene-diene) (EPDM)	77.40
25	11.51	0.19	Poly(propylene) (PP), atactic	95.70
26	18.18	0.55	Poly(ethylene-propylene-diene) (EPDM)	77.50
27	24.96	0.23	Polyamide 6 + Polyamide 6.6	68.89
28	16.43	0.65	Poly(ethylene-propylene-diene) (EPDM)	77.40
29	27.90	0.25	Poly(ethylene-propylene-diene) (EPDM)	77.40
30	36.82	0.38	Poly(ethylene-propylene-diene) (EPDM)	77.40
31	21.26	0.39	Poly(ethylene-propylene-diene) (EPDM)	77.40
32	20.42	0.51	Polyamide 6 + Polyamide 6.6	68.89
33	18.93	0.67	Poly(ethylene-propylene-diene) (EPDM)	77.40
34	23.13	0.19	Polyamide 6 + Polyamide 6.6	68.89
35	15.47	0.59	Poly(ethylene-propylene-diene) (EPDM)	77.40

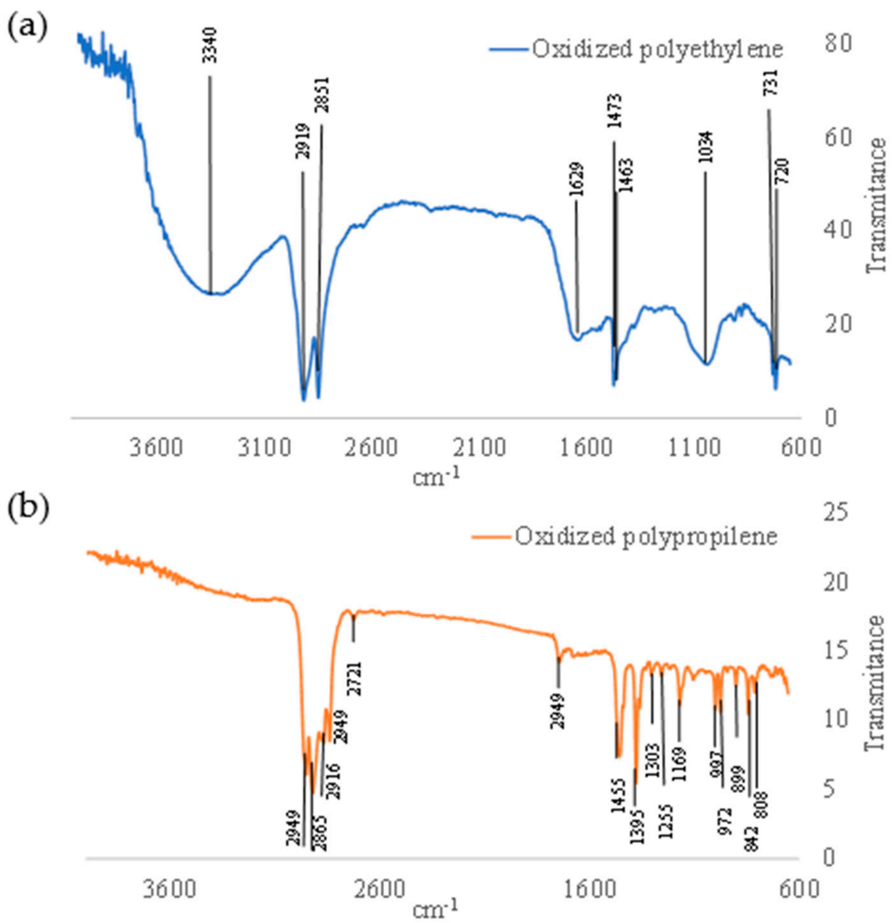

Figure 4. Infrared spectrum of plastic samples identified with the FT IR library; (**a**) oxidized PE and (**b**) oxidized PP.

Measurements were taken for each plastic piece to determine the circularity and diameter, typically known as roundness. Roundness indicates how close to a circle the measured shape is, with one being the exact value, meaning having conformed to a circle shape. Among all the plastics collected, the presence of at least one microplastic

(MP < 5 mm) was identified, since particle number 3 had an approximate diameter of less than 5 mm, which classifies it in the category of plastic pollutants.

At least four types of plastics were identified from all the pieces collected from the sample, where 76.67% was identified as polyethylene (PE), 65.71% as propylene (PP), 57.14% as PA, and 2.85% as acrylonitrile butadiene styrene (ABS) from all plastics collected. In addition, PE in its oxidized state was found in this soil sample, indicating that the plastic was in the degradation phase. Even though the presence of MPs was identified, this does not mean that there were not more of the MPs with smaller particle sizes, since they were not examined at a higher magnification on the microscopic scale.

3.1. Origin of Plastics in Soil and Agricultural Lands

In the garden sample studied, the main origin of plastics was composting. In some countries, including Canada, municipal services separate inorganic waste from organic waste, and organic waste is delivered to the composting companies through "green bin" programs. Organic waste is then "treated" at the composting facility and is subsequently sold "as is" or in soil mixes for agricultural use. When the separation of organic matter occurs in homes or businesses, this separation can be imperfect, and plastic can end up contaminating the organic waste. In "green bin" programs, information brochures are distributed to notify residents and/or businesses what materials are allowed to be disposed of with organic waste; however, these campaigns are not sufficient enough to deter people from throwing, sometimes unknowingly, various plastic packaging into their "green bins". Current rules around composite quality allow for small pieces of plastic to find their way to the compost that is sold because of an imposed limit on foreign material being based on the weight percentage [37,38].

Agricultural lands and farmlands may have additional sources of plastics such as from the utilization of plastic fertilizer bags as mulch films to cover soil, greenhouse films, biosolids from wastewater treatment, and atmospheric deposition (wind transported). The practice of using plastic covers on agricultural soils is widely used to maintain humidity and thus increase the productivity of the crop. This practice has led to a substantial accumulation of plastic fragments in soils in China, reaching concentrations of 50–260 $kg \cdot ha^{-1}$ in the surface layer. Sometimes, the plastic is not removed and undergoes partial degradation with fragmentation into smaller particles such as MP [39]. The ultraviolet radiation, interaction with water, air oxidation, and the actions of microorganisms cause polymeric molecules to break down into smaller and smaller parts, creating MPs and NPs [14].

Biosolids from wastewater treatment plants are used as fertilizer, and it has been reported that this also can become a source of plastic contamination in terrestrial environments [40]. In a study on biosolids in Ontario, Canada, the concentration of MPs in biosolids was found to be between 8.7×10^3 and 1.4×10^4 particles per kg. In the same study, it was mentioned that farmlands received an additional 4.1×10^{11}–1.3×10^{12} of particles annually [41]. Therefore, there are different occurrences of soil contaminated with plastics. Table 2 shows some occurrences of plastic and microplastic contamination reported in the literature.

Table 2. Different occurrences of soils contaminated with plastics and MPs.

Source	Research Area	Types of Plastic Found	Diameter	Concentration	Ref.
Landfill	Iran	LDPE, PP, and PS	0.1–100 mm	863 ± 681 and 225 ± 138 particles.kg^{-1} of soil for microplastics and 29.8 ± 6.4 and 18.1 ± 8.3 particles.kg^{-1} of soil	[42]
Composting	Finland	-	-	6.5 g.kg^{-1} or 1.5 pieces.kg^{-1} of soil of macro-, meso-, and microplastics	[43]

Table 2. *Cont.*

Source	Research Area	Types of Plastic Found	Diameter	Concentration	Ref.
Composted organic fraction of municipal solid waste	Spain	PE, PS, polyester, PP, PVC, and acrylic polymers	0.5–30 mm	10–30 items·g^{-1}	[44]
Composting	Germany	PA, polycarbonate, LDPE, HDPE, PET, PP, PS, PVC	higher than 5 mm	ranging 12 ± 8 to 46 ± 8 particles.kg^{-1} (0.05 ± 0.08 to 1.36 ± 0.59 g.kg^{-1})	[45]
Farmland/mulching	China	Polystyrene (PS), PP, oxidized PE, LDPE, PE	15% minor than 1 mm, 65% with 1–3 mm, 12% with 3–5 mm, 8% higher than 5 mm	12–117 particles.m^{-2}	[15]
Composting	Switzerland	-	-	1390 ± 390 tons of plastic accumulate in Swiss soils since 1985	[32]
Beach sand	Thailand	PET, PS, PP, PU, PVC, Epoxy	20–300 µm, and higher than 300 µm	188.3 items.kg^{-1}	[46]
Landfill	Bangkadesh	LDPE, HDPE, and cellulose acetate	0–2000 µm	-	[47]
River sediment	Thailand	PP and PE	0.05–0.3 mm	91 ± 13 items.kg^{-1} or 4.9 ± 3.4 mg·kg^{-1}	[48]
Wastewater treatment plant (sewage sludge)	Canada	PS, PP, nylon, PA, polyester	-	16 particles·g^{-1} (primary sludge) and 4 particles·g^{-1} (secondary sludge)	[49]
Swiss floodplain soils	India	PE and PP	-	An average of 106 micropellets.m^{-2}	[50]

Aspects of Plastic Pollution in Canada

The Federal Government of Canada has recently completed a scientific review of the effects of plastic pollution on human health and the environment [38]. The definition of plastic pollution originates from plastic that has been discarded or abandoned in the environment. Often, plastic pollution comprises single-use straws, plastic bags, food containers, and one-time use cutlery and sometimes can result from a spillage of fishing gear [51]. Plastic can be divided into at least two categories based on particle size: MP is considered to have a diameter larger than 5 mm, and MP is particles smaller than this. This review identified some important environments where plastic tends to accumulate: (1) along the shores of lakes and oceans, (2) in the bottom sediments of waterways, (3) floating in surface waters, (4) groundwater and drinking water; these have also been reported in other research [52–55].

MP pollution often occurs as a result of improper waste management such as "littering", or the spillage of waste during transport. When plastic contaminates water, it can change habitats, and sea fauna can become physically entangled in the plastic and/or they can ingest it. The plastic contaminating the garden soil in this study was a result of possible mismanagement of organic waste. Households not adhering to the ban on plastic within green bins are responsible for this type of MP pollution [56]

In Canada, the production of plastic is mostly from virgin materials (i.e., not recycled), and these plastics are primarily disposed of in landfills. Recycling collection rates indicate that only 25% of plastic produced is being sent to a sorting facility. For the plastic that reaches that facility, only 30% of it is recycled due to contamination with other materials. Additional reasons for the absence of a circular economy for plastic are: (1) inconsistent feedstocks for recycled resin, (2) a labor-intensive cost structure for the production of recycled resin, (3) a lack of demand for recycled plastics, (4) disposing in landfills is relatively inexpensive, (5) costs of plastics are shouldered by individuals and communities (management of urban roadside litter).

Single-use plastics have been defined as those designed to be thrown away after being used only once [57]. These plastics are generally used as packaging (food wrappers, shopping bags, beverage bottles), convenience items (drink cups and lids, straws, stir sticks), and some serve as essential items (supplies in the dental and medical industry) [51].

In 2018, federal, provincial, and territorial governments in Canada collaborated to create the "Canadian Council of Ministers of the Environment Strategy on Zero Plastic Waste". This strategy focused on preventing plastic waste, collecting all plastics, and recovering value from plastics. The aim was to redefine plastic waste as a valuable commodity where a circular economy could be applied [58].

3.2. Canadian Regulations on Single-Use Plastic

During the creation of a management plan for single-use plastics, the Government of Canada recognized specific single-use plastics that are necessary to keep Canadians safe and healthy, to improve accessibility for people in need, and to keep food preserved. Single-use plastics were also categorized into "environmentally problematic" and "value recovery problematic" groups. Two management strategies were then employed to the plastics: completely eliminate from or reduce in the Canadian market or increase recycling with improved recovery rates.

In July 2021, the provincial government of British Columbia amended the Community Charter, B.C. Reg. 144/2004, "Spheres of Concurrent Jurisdiction—Environment and Wildlife Regulation", to allow any municipality to "regulate, prohibit and impose requirements in relation to the protection of the natural environment" [59]. This regulation gave municipalities the power to prohibit single-use grocery bags, polystyrene foam service ware containers, plastic utensils, and plastic drinking straws. It also lists prices that businesses must charge for providing paper bags and reusable bags. Several exemptions were listed to be applied to persons with disabilities, for medical reasons, to hospitals and community care facilities, and for reasons of financial hardship.

In June 2022, Single-use Plastics Prohibition Regulations: SOR/2022-138 were set into action in Canada [60]. This regulation prohibits the manufacturing, import, and sale of six categories of single-use plastics. These categories are grocery checkout bags, cutlery, food service ware, ring carriers (rings holding four- or six-pack drink cans), stir sticks, and straws. There are some exemptions related to accommodation for persons with disabilities. The rationale behind implementing this regulation was that single-use plastics are the most common component of litter both domestically and globally. Adopting this regulation was expected to result in a decrease of over 1 million tons in plastic waste over the next 10 years (2023 to 2032), while it is expected that approximately 22,000 tons less of plastic will still pollute the environment.

Despite the implementation of both municipal- and federal-level bans on selling, manufacturing, and importing single-use plastics in Canada, plastic pollution still exists, and an area that is being overlooked at the present time is plastic pollution in garden compost. Garden compost quality is regulated at the provincial level in Canada, and at this time, the regulations do not treat plastic waste differently from other foreign materials such as glass, metal, or wood when checking compost quality.

British Columbia Compost Regulations

The Organic Matter Recycling Regulation of B.C. of 2002 governs the construction and operation of compost facilities and the production, distribution, storage, sale, and use of biosolids and compost. It also includes schedules which outline the processes for reductions in pathogens and pathogen limits, vector attraction reduction, quality criteria, sampling and analyses, record keeping, and land application plans [61].

The regulation does not address the issue of plastic contamination specifically. Within the quality criteria rules, the regulation states "Retail-grade organic matter and managed organic matter must have a foreign matter content less than or equal to 1% dry weight". Plastics are broadly lumped into the category of "foreign matter" and are not treated differently [61]. This becomes a problem when the individual pieces of plastic are in the form of bags, films, and other low-density plastic types. For instance, plastics tend to have a lower density than other matters such as wood, metal, ceramics, and glass.

In this study, as explained in Table 1, 35 pieces of plastic (with 1.7 g in total) were found in a sample with more than 2 kg, which could represent less than 0.1% in w.w^{-1}. However, the related toxicity of this concentration is unknown. Although the legislation is specific in establishing a limit on the metal content in composting, the text itself presupposes that more restricted positions regarding the composition of foreign materials should be considered in the future. However, considering current publications that report MPs found in different levels of the human food chain, including in community gardens, this resolution requires more importance and urgency in discussions.

The problem of plastic contamination is most serious when composting facilities collect organic waste from private households. Figure 5 is a picture from the garden sample with plastics in the roots of plants. Due to the light weight, the difficulty of measuring, and the irregular shape, it is more common for contaminations to be reported in particles per kg in the scientific literature [62,63]. Because of this, the legislation around plastic contamination should be more specific to differentiate materials and to establish appropriate allowable concentrations. There is a research gap in the knowledge of a proper and standardized methodology that gives the exact concentration of MPs and NPs, and it is challenging to establish the minimum discard limits in solid samples.

Figure 5. Soil from the household garden contaminated with plastics in the plant's roots.

Although municipalities often have auditing programs where the contents of organic waste "green bins" are checked for foreign non-organic contaminants, plastic is still finding its way into these green bins and then is making its way past quality control testing and into urban gardening and green spaces such as recreational parks.

Recently, an update was published by the government of British Columbia, referred to as "Organic Matter Recycling Regulation Project Update, June 2022", where new limits on foreign matter were listed. This document recommended that in addition to the current regulation requiring the measurement of foreign matter as a percentage of dry weight, the grab sample will be required to have less than one piece of foreign matter > 25 mm in any

500 mL sample for Class A compost and less than two pieces for Class B compost. This addition to the regulation does not address the plastic contamination issue and would still allow for a large amount of low-density plastic particles less than 25 mm to be introduced to and contaminate the compost [64]. Among the particles observed in this study, at least four particles with diameters greater than 25 mm were identified (plastics with numbers 16, 20, 29, and 30 in Table 1). Given that the study sample was a random grab sample, conclusions cannot be drawn on whether the composting facility complied with legislation or if there was an accumulation of plastics from successive composting. A more comprehensive study would need to be completed, looking at several community garden organizations and many garden plots.

Research into plastic contamination is relatively new. For example, according to [65], an increase in the number of publications about MPs and NPs in garden soils has grown from 100 papers in 2017 to 800 papers in 2023. There is a common agreement in the literature regarding the lack of understanding of how toxicity can reach higher levels in food chains. In addition to the difficulties in characterizing plastics, measuring the concentration by weight of macro, micro, and NPs in soils still presents a major challenge [39,66]. However, the interactions between these contaminants and the environment must also be understood so that legislation is better directed to the benefit of society.

3.3. Interactions of Plastics with Plants, Animals, Microorganisms, and Their Toxicity

The effects of plastics in soils are still debatable, and there are studies that conclude that certain concentrations of these materials do not affect plant growth. In the study conducted by [67], it was highlighted that low concentrations of plastic fragments in soils cultivated with *Arabidopsis thaliana* increased the water content in the clay-rich soil; it is believed that it created higher porosity in soil, resulting in better aeration and water transport. However, the opposite effect was observed in clay-rich soils with plastic concentrations above 0.1% in its composition and under the conditions of water scarcity. Previous studies demonstrated that plastics could affect not only the enzymatic activity of plants but also the pH and microbiota of the soil.

Ref. [68] studied the toxic effects of different types of microplastics—specifically, polystyrene (PS), polyethylene (PE), and PP (PP)—on tomato plants (*Lycopersicon esculentum* L.). The study aimed to examine how different types and concentrations of MP affect seed germination and growth in tomato plants. A hydroponic setup was used to explore the effects at different concentrations (0, 10, 100, 500, and 1000 mg·L^{-1}) of MP on the plants. All three types of MP (PS, PE, and PP) had inhibitory effects on the germination of tomato seeds at concentrations up to 500 mg·L^{-1}. In comparison with the control experiment (without plastic), the germination rate was 10.1–23.6% less in samples with plastics. Surprisingly, the inhibitory effect was reduced when the concentration of MP was increased to 1000 mg·L^{-1}. Among the three types of MP, PE was found to be more toxic to the seedling's growth compared to PS and PP. The study also found that MP induced oxidative stress in plants. Among the types tested, PP was less toxic to antioxidant enzymes compared to PS and PE. The study concluded that the findings could serve as a theoretical basis for future research on the toxic effects of MP on tomatoes and help in understanding the specificity of MP's toxic effects on plants [68].

In both studies, plastic particles differ in the size of the analyzed plastics; while the first study performed analysis with LDPE fragments between 4 mm and 8 mm (MP and MAs), the second uses NPs of 52.48 μm–368.13 μm. However, the presence of MPs in the soil is also reported to be generated from interactions with the soil (photochemistry, moisture, heat, and chemical reagents present) [69], and, despite the high stability of the polymetric matrices, these phenomena resulted in several interactions with the plastic, which is fragmented into NP and MP particles. The way of isolating these materials from solid matrices is frequently discussed in the literature and can be through physical separations (manual picking, density, magnetic, electrostatic, and filtration) and chemical separations (digestion or extraction by solvents). However, there are no standardized or prescribed methods of separation from soil matrices, making the process of adequate removal of these contaminants difficult [17].

The risks associated with the presence of MP in soils are widely discussed, but they gain prominence in soils that are intended for agricultural use. Plastic fragments not only hinder the exchange of nutrients within the plant, but they also interfere with soil moisture and increase the mobility of polluting substances in the soil. In addition to impairing the diversity of bacteria and fungi [69,70], discussed various interactions that occur between pesticides and MP present in the soil for cultivation. In general, it was observed that the presence of MP in the soil acts as a carrier of pesticides to deeper layers of the soil, traveling 30–50 cm deep, reaching roots and affecting the local microbiota [40]. This occurs through adsorption and desorption between plastics and pesticide molecules, reported in several studies [71–73]. PP, for example, is naturally hydrophobic, which facilitates its interaction with molecules of the same character. It is worth mentioning that pesticides are substances that have persistent, cumulative characteristics in organisms and, consequently, are difficult to degrade. The penetration of these substances into plants and aquatic environments is debatable and potentially harmful to animal and human health [63].

Currently, research has also focused on understanding the risks of nanometric plastic particles (NP), but the difficulties of analyzing plastics in complex organic matrices presents a significant barrier. However, there are studies that demonstrate that the absorption of NP by plants is similar to that of nanometric particles [74]. Unlike animal cells, plant cells are able to limit the absorption of nanoparticles. This occurs because plants have several protective tissues layers such as the phospholipid bilayer cell membrane, cellulose cell membrane, and coextensive pectin network. Nonetheless, negatively charged particles on their surface can move through microscopic extracellular channels, reaching the vasculature that transports water (apoplastic transport), and these NP can reach the stem, leaves, and fruits [75].

The contact of plants with NP is not only limited to the absorption of plastic substances, as polymetric matrices can be associated with pollutants (such as pesticides), or even polluting with heavy metals. Ref. [74] demonstrated that even positively charged NP can reach the plant vasculature, as plants activate a defense mechanism resulting in the production of exudates (oxalate) that house the NP in aggregates.

On the other hand, the level of phytotoxicity depends on several factors, such as MP particle size, type, and the media exposed. In a study where different levels of Cd, PE, and polylatic acid (PA) were exposed, it was observed that biodegradable plastics can alter the properties of the growth profile and diversity of arbuscular mycorrhizal fungi (AMF) cultures, in addition to pH and plant growth, while more stable plastics showed little or no influence. The results were observed using concentrations of 5 mg$\cdot$kg^{-1} of Cd and 0.1%, 1%, and 10% (mg of MP per kg of sample), which according to the authors, are acceptable levels of contamination in Chinese soils. However, it was claimed that the time used in this study may have been insufficient, suggesting that further studies are needed with PE-MP already degraded in long-term experiments [76].

Other compounds such as plasticizers, antioxidants, flame retardants, and substances toxic to human health are present in the composition of plastics. Several studies have already reported the presence of petroleum derivatives such as polycyclic aromatic hydrocarbons (PHAs), phthalates, and acetyl tributyl citrate (ATBC). Furthermore, metals such as cadmium, cobalt, and lead are also reported. Scopetani et al. (2022) [43] carried out contaminant analysis on four soil samples from pea, bean, and barley agriculture, two of which used waste from composting companies as fertilizer (once a year), one of which used it for more than 1 year, and the fourth one never used it. In this study, analyses of bis(2-ethylhexyl)phthalate (DEPH), ATBC, and several metals were performed. Furthermore, physical separation was carried out by sieving the samples to remove plastics (macro-, or with a diameter above 25 mm, and meso-, with a diameter between 2 and 25 mm). It was detected in samples from fields that used composting waste as fertilizer; DEPH was detected with concentrations of 931 $\pm$ 163 ng$\cdot$g^{-1} for the barley field and 1080 $\pm$ 209 ng$\cdot$g^{-1} for the bean. ATBC was also detected at concentrations of 207 ± 27 ng·g^{-1} and 102 ± 21 ng·g^{-1}, respectively. In samples where plastics were separated from the soil, 2610 ± 1290 ng·g^{-1} of DEPH was detected, and the ATBC was below the detection limit. Organic contaminants were not detected in the other soils (which did not use compost as fertilizer and were used more than 1 year ago). Metal analysis indicated that there was no transfer of metals to the soil despite concentrations of metals with toxic potential such as Cr (between 23 and 73 ng·g^{-1}) and Pb (between 2.8 and 18 ng·g^{-1}) being detected. As a result, the study concluded that there is a transfer of organic compounds present in the composition of plastics to the soil. As a warning, the importance of investigating the migration of metals in the presence of MPs, according to each type of vegetal species in plantations that use composting as a fertilization method, was highlighted to deepen the safe levels of contamination. However, despite the absence of migration of metals from plastics to the soil being reported, it is important to highlight that the authors reported that the studied environment did not suffer from sudden changes in the climate, which remained relatively stable.

The question of the relationship between macro-, meso-, and MP and metals is intrinsic to the adsorption and desorption effects. From external actions such as sun, air, and microorganism effects, MPs in contaminated soils are subject to cracks, and changes may appear on the surface of the material, thus acquiring more adsorption capacity. Factors such as pH, salinity, and soil moisture can contribute, and, through this, metals such as Cr, Pb, Ba, and Cu can adsorb through physical interactions [77]. According to [76], increasing the concentration of MP in the soil increases the mobility of the present Cd in the soil. This occurs because, in soils contaminated with MP, there is less adsorption of Cd by the soil, and consequently, greater desorption of Cd. Conversely, the opposite occurs in soils free of MP. This dynamic puts the balance of agroecosystems at risk, according to the study. On the other hand, it was shown that acidic soils increase Ag desorption from MPs. Hence, there are specific conditions for each type of plastic and metal in question. Therefore, combined with studies that already report the presence of MP in foods and drinks consumed by humans, exposure to toxic metals related to MPs must also be taken into consideration [77,78].

3.4. Plastic Degradation

In terms of degradation, plastic is a chemically stable material with slow biodegradation. Therefore, biodegradation processes are long-term, but can be accelerated via mechanical action, UV irradiation, high temperatures, and many other factors [79]. The action of UV or photodegradation is the natural way in which polymer decomposition occurs. The deeper in the environment (soil or water) the plastic fragments are, the less interaction with light is to become photodegraded; however, the polymers are also decomposed through free radicals generated by the action of photons from ultraviolet rays with soil humidity or other substances. Due to the absence of chromophore groups in the PE structure, photodegradation does not occur, but it is possible with some impurities in its composition. However, photodegradation of PE occurs from vinyl and ketone groups that are decomposed into alcohols, carboxylic acids, ketones, aldehydes, and esters through interaction with the free radicals formed [80].

Ref. [81] studied the photodegradation of PE, PP, and PS in three different scenarios: in air, in ultrapure water, and in simulated ocean water. In the experiments, a UVA lamp with a wavelength of 340 nm was used to simulate sunlight, where each sample was subjected to 3 months of exposure. Through FTIR analysis, it was observed that there was a formation of absorption peaks in the regions of O-H bonds at 3300 cm^{-1} and C=O at 1712 cm^{-1} that increased over time. However, in the air exposure condition, differently from the experiments with water, the presented absorption peaks were more evident, which is clear evidence of more interaction or degradation. Thus, the authors suggested that contact with molecular oxygen in the air damaged the structure of plastics more than contact with water.

The biodegradation of PE can also occur through the action of fungi and bacteria that can be in commensal or symbiotic relationships with other living organisms (mainly invertebrates). Examples of living organisms harboring microorganisms capable of biodegrading PE are mealworms (*Tenebrio molitor*), superworms, wax moths (*Galleria mellonella*), and scale insects (*Planococcus citri*). Furthermore, it was also found that LDPE by-products from *Zophobas atratus* larvae break down polymer molecules into smaller parts, i.e., MP and NP. However, it is worth noting that these processes are slow and have a slow conversion rate. Additionally, what is found in most of the studies is that the plastics are not completely removed but just suffer a mass loss. In this way, MPs (diameter more than 5 mm) could be transformed into microplastics MPs (diameter less than 5 mm) or NPs (diameter less than 100 nm). For example, it was demonstrated that the species of larvae *Tenebrio obscurus* and *Tenebrio molitor* degrade LDPE. This was observed through a decrease in the molecular weights of the compound of 34–45.4% for the first species and 31.7–43.3% for the second in 35 days [82]. In the same way, [83] found that waxworms (*Plodia interpunctella*) degrade 6.1–10.7% of PE in 60 days, also resulting in 12 substances that are soluble in water. Thus, it was observed that the degradation of plastics by microorganisms can result in smaller particles as well as by-products that are not easily recognizable or whose chemistry is not well understood. The transport of MPs can be also promoted by earthworms, termites, and ants taking them to deeper layers, making them available in water or plants' roots.

One of the ways pollutants reach riverbeds is through irrigation, so MP and its by-products can be drained or absorbed by plants. Generally, polymeric plastic molecules are highly resistant to degradation, are not fully digested in living organisms, and are bioaccumulative [39]. The presence of MP in soils used for vegetable farming can become toxic for human consumption, although researchers admit that more studies are needed. There are studies that link MP consumption with human cellular stress and side effects in animals such as mice. Ref. [84] carried out studies with the internalization of PE-MPs in human epithelial cells and observed that a concentration of 1 $mg{\cdot}L^{-1}$ was sufficient to slightly reduce the cell viability of Caco-2 intestinal epithelial cells and lung epithelial cells, in addition to stimulating the generation of reactive oxygen species (ROS) in immune cells THP-1, Jurkat, U937.

In another study, rats were subjected to 5 weeks of ingestion of different concentrations of MP-PE (6, 60, and 600 $\mu g.day^{-1}$), and the effects of exposure were analyzed. The results demonstrated that there was an increase in the number of microbial species, but mainly *Staphylococcus*, and a decrease in *Parabacteroides*. The levels of interleukin-1α, a substance associated with inflammatory processes and a decrease in cells in the intestinal tract, were also increased. The balance between these substances is related to mucosal immunity and intestinal defense, which shows that exposure to MP-PE changed the organism of mice [85].

It is important to highlight that studies differ in relation to the demonstration of toxicological effects in concentrations and particle size, but mainly the type of MP. For example, it was observed by [86] that the exposure of PS-MP to human cells of the THP-1 line, with three ingestions of 4.55×10^7 particles of different sizes (1 μm, 4 μm and 10 μm) per week, practically showed no effect. However, it is possible that in the above-mentioned study, they used concentrations above those found in foods such as apples, pears, lettuce, and potatoes. Ref. [87] determined MP levels in fruits (*Malus domestica* and *Pyrus communis*) and vegetables (*B. oleracea* italic, *Lactuca sativa*, *Daucos carota*, and *Solanum tuberosum*) purchased at markets and supermarkets in the city of Catania, Italy. It was observed that the average contamination level was 223,000 pieces of plastic (52,600–307,750) for fruits and 97,800 pieces (72,175–130,500) for vegetables. However, contamination results may vary from region to region; therefore, it is clear that studies are needed to investigate the levels of MPs already intrinsic in other locations.

An imminent danger of MP contamination is the possible ingestion by humans, which can occur through contaminated food or water. A possible form of this mechanism is through composting intended for gardening, horticulture, and also for agriculture acting as fertilizer. However, as previously mentioned, waste from composting in urban homes is not only stored in plastic bags but also contains other polymers mixed in. For example, in the sample analyzed in this article, plastic bags used in fruit packaging and also fragments of fabric (such as nylon) were found. Once stored in the soil in external environments, the soil mixed with composting waste and plastic is subject to the action of ultraviolet radiation, which will begin the degradation process of the polymers present. In parallel, living beings such as worms, beetles, and microorganisms also participate in the decomposition process, transforming polymeric residues into smaller parts such as MPs and NPs. This process makes these particles more easily assimilated by plants and easier to absorb through their roots. Furthermore, MPs are also transported to other locations through air currents, or travel through deeper layers of soil and groundwater. The result of these phenomena is the contamination of vegetables and water intended for human consumption, whether directly or indirectly, since even if this water is not consumed directly, it can be used to raise animals or irrigate agriculture. A schematic showing the pathways of plastic contamination is represented in Figure 6.

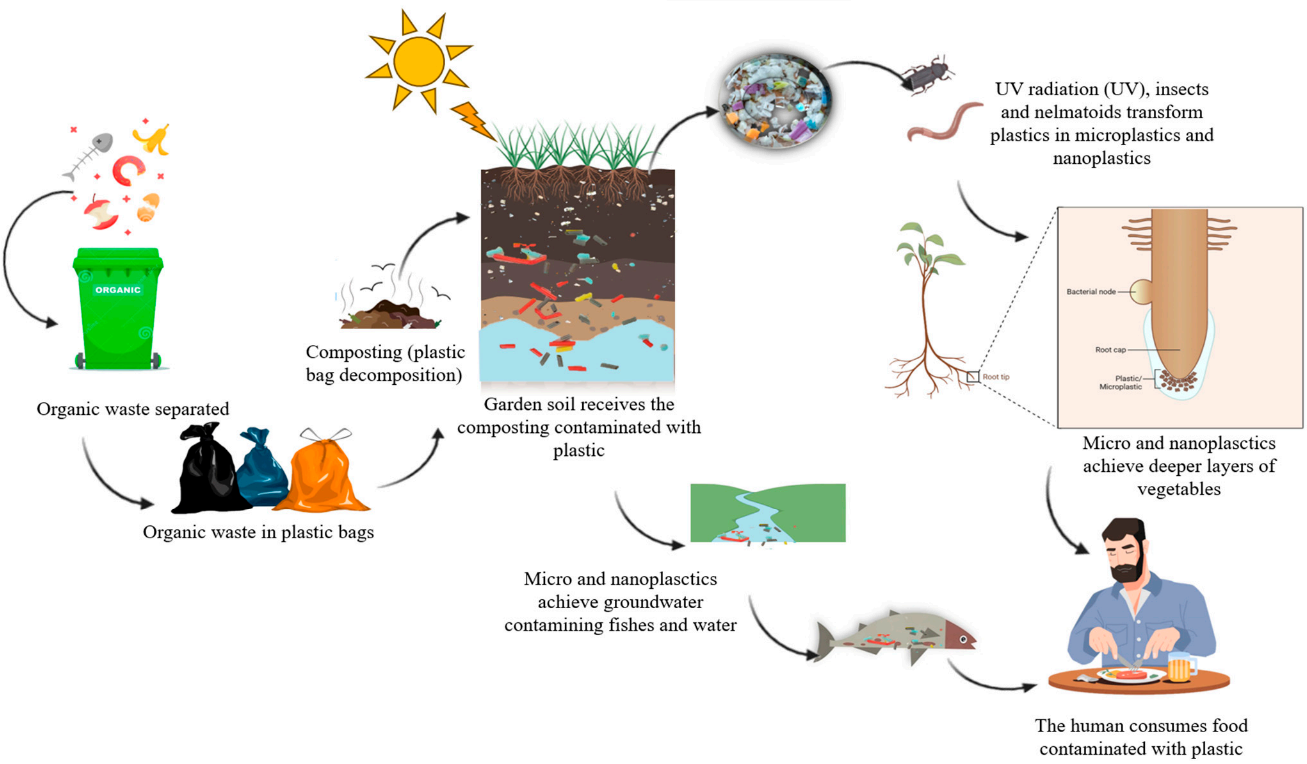

Figure 6. Plastic contamination affecting the environment and human health.

3.5. The British Columbia Regulation and a Discussion of Plastic Presence in Composting

After the discussion elucidated around the plastic contamination found in soils from gardens and agricultural land and the dangers involved in human health, it can be observed that the current legislation regarding the use of compost as a fertilizer in agricultural land requires detailed discussion. Currently, studies still do not fully understand what safe levels of plastic contamination are for samples intended for cultivation. However, several studies highlight the presence of MP in food and water intended for consumption, and it has also been reported in the human body itself [78,88]. The toxicity levels of MPs are also still poorly known; however, there are already studies that report deaths in rats in addition to metabolic changes. Another important variable is the behavior of substances such as flame retardants and plasticizers in plastic compositions that appear to have different interactions depending on the type of medium inserted. These contaminants are already known as dangerous to human health; however, their presence in plastics is not considered in legislation or safe limits of plastic concentrations on soils. The same could be said for the metals found in plastic composition. A curious relation is that besides the legislation being truly clear about metal concentrations in commercialized composting, nothing is said concerning the metals present in plastics.

As noted from the literature review, the effects of plastics on organisms in soils are not completely understood. However, it has been noted that some studies demonstrated that plastic contamination in cultivable soil did not present any changes in plant growth or the life of terrestrial organisms, while other studies reported the opposite. In general, it is observed that plant growth and the life of terrestrial organisms depends on the following variables: plastic particle size, concentration, type, and environmental conditions (pH, humidity, and available substances such as pesticides, metals, or pollutants). This demonstrates how complex it can be to establish a limit of the amount of waste that is allowed to be included compost. As discussed, there is evidence that depending on the level of exposure to MP, this can cause changes in human cells and cause oxidative stress in terrestrial organisms, in addition to intoxication and possible death. It is important to highlight here that organisms such as nematodes, earthworms, insects, as well as bacteria and microorganisms are essential for maintaining the biological growth cycle of plants, as they help with aeration, homogeneity, and maintenance of humidity.

In this way, this topic deserves attention and studies that deepen knowledge about damage to human health. It is urgent to determine safer legislation on the subject. It should be noted that the practice of composting is important for contributing to the disposal of waste that would later go to landfills and thus contribute to sustainable development; however, the safety of this practice is a preponderant factor.

4. Conclusions

In this paper, we studied an example of soil contamination in garden soil from a community garden in British Columbia, Canada. Plastic contamination in oceans and fresh water sources has been widely discussed in the literature; however, plastic pollution in urban and agricultural soils is also becoming a pervasive pollutant in the environment. In British Columbia, current regulations governing composting state that when compost from food sources has less than 1% of its dry weight representing foreign materials (including plastic), it is still allowed to be used in soils. In the studied sample, we found plastic particles of various sizes and shapes present in garden soil. We analyzed them using micro-FTIR spectroscopy, and we identified more than four types of plastics in the studied sample, 76.67% of which was polyethylene (PE), 65.71% was propylene (PP), 57.14% was polyamide (PA), and 2.85% was acrylonitrile butadiene styrene (ABS). In addition, PE was found in its oxidized state, indicating that the plastic was in the degradation–decomposition phase. During the collection of plastic particles, we found particles larger than 5 mm in size with at least one plastic particle that was smaller than 5 mm (microplastic), which is an indication that more microplastics may have been present in the studied soil. In this work, we concentrated on analyzing MPs, larger plastic particles which were visible by naked eye (macroscopically), in garden soil.

In view of the legislation in British Columbia, Canada, it is suggested that this specific regulation related to the concentration of plastic in soil may need to be re-addressed, because the current regulation for composting allows for 1% of foreign matter content on a solid weight basis, which could be already too high since plastic particles are very lightweight. Our results showed that garden soil prepared from compost was enriched in plastic particles that can produce MP particles by either physical, chemical, or biodegradation. One sample was collected in this study as a "sniff test" to test quantification and qualification methods for plastics. A larger sample set should be collected in future studies when statistical analysis is required. In addition, it is necessary to standardize the methods for quantifying plastics in contaminated soil, since the manual physical separation method may be insufficient, because these particles may be present in the media in micron size and at the nanoscale. Finally, it is concluded that it may be necessary to revise compost regulations following more detailed research into microplastic pollution in soils in order to recommend specific legislation to address each plastic type as an environmental contaminant.

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