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Review

Review of Current Issues and Management Strategies of Microplastics in Groundwater Environments

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Abstract: Microplastic contamination has become widespread in natural ecosystems around the globe as a result of the tremendous rise in plastic production over the last 70 years. However, microplastic pollution in marine and riverine habitats has received more attention than that of terrestrial environments or even groundwater. This manuscript reviews the current issues, potential occurrences, and sources of the emerging problem of microplastic contamination in groundwater systems. The most prevalent types of plastic detected in groundwater are polyethylene and polyethylene terephthalate, and fibers and fragments represent the most commonly found shapes. The vertical transportation of microplastics in agricultural soils can affect groundwater aquifer systems, which is detrimental to those who use groundwater for drinking as well as to microorganisms present in the aquifers. Moreover, this review sheds light on the interlinkage between sustainable development goals and groundwater microplastic contamination issues as part of the strategies for the management of microplastic contamination in groundwater. Overall, this review reveals a lack of interest and a gap in knowledge regarding groundwater microplastic pollution and highlights future perspectives for research in this area.

Keywords: groundwater contamination; microplastic; drinking water; fibers and fragments; soil

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1. Introduction

Groundwater is used for various purposes by almost two billion people worldwide, such as for drinking and agricultural, residential, and industrial functions [1]. According to recent reports, groundwater is contaminated by microplastics [1–5]. Plastic products, which have played a vital role in global society since the 20th century due to their unique properties, represent the source of microplastics. Plastic can conveniently be shaped into any design by applying temperature or pressure and these products are immensely useful and ubiquitous in daily life, such as for packing food and other materials. Plastic production has increased from 5 Mt in 1950 to 367 Mt in 2020 [6] (Figure 1). The materials employed to build utensils and other fundamental items are frequently used to depict human history and advancement [7]. Mankind has progressed through the rock, bronze, iron, and copper ages and is now widely considered to be in the digital age. However, an alternative perspective is that mankind is currently in the plastic age [8] owing to the pervasiveness of plastic in human life.

When plastic waste is disposed of in the environment, it degrades into smaller sizes [9–12]. Plastic pieces with diameters of <5 mm are referred to as microplastics [13,14] and can be divided into primary and secondary microplastics (Figure 2). Primary microplastics are released directly into natural environments and originate mostly from body and skin care products, industrial wastes, and textile applications [12,15–17]. Secondary microplastics originate from the fragmentation of larger plastic particles into smaller particles that are degraded in the environment due to ultraviolet exposure from the sun as well as from chemical, physical (such as washing machines), and mechanical weathering (such as tidal waves) [18,19]. Most microplastics in the environment are secondary microplastics and they, together with primary microplastics, pose a threat to the environment [4,20–22].

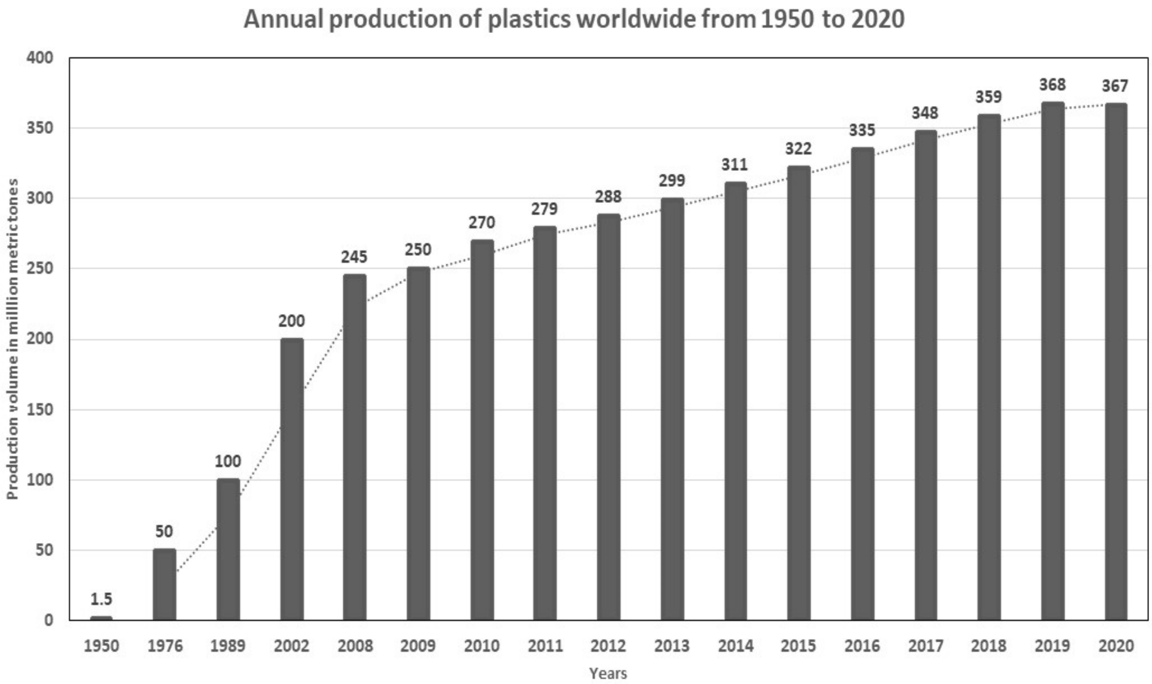

Figure 1. Annual production of plastic worldwide from 1950 to 2020 (Plastics Europe, 2020).

In 2015, approximately 6300 Mt of plastic waste was produced. Of this waste, 9% was recycled, 12% was incinerated, and 79% was disposed of in landfills or natural environments [23,24]. In addition to natural environments, plastic waste has been found in sea salt, table salt [25], and beer [26]. In recent years, there has been increasing research on the presence of microplastic contaminants in marine, river, and lake environments [27–34]; however, little attention has been paid to microplastic contamination of groundwater on a global scale. This could be because groundwater microplastic contamination is still in its early stages [35]. However, it presents an emerging concern [36].

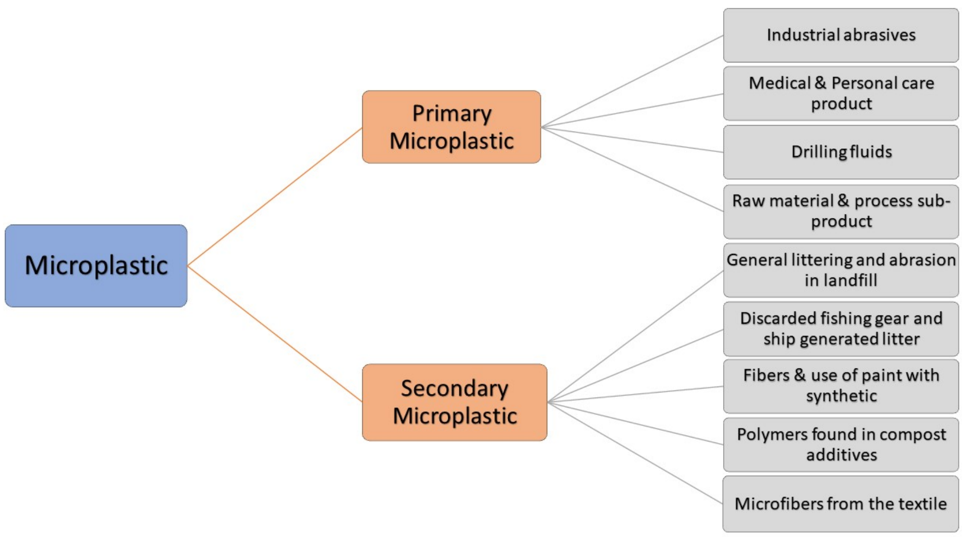

Figure 2. Main sources of primary and secondary microplastics. Adapted from [37].

Groundwater microplastic pollution has been less studied than that in other natural environments such as marine, river, aquatic, and soil (Figure 3). Soil can act as a barrier to groundwater microplastic pollution, which could explain why researchers have not focused on groundwater microplastic pollution [5]. However, soil microplastic pollution has increased in recent years [38–44] and soil is the most likely route for microplastics to enter the groundwater system, meaning that the rise in microplastic pollution in soil in recent years is a point of concern. Previous studies have identified the vertical transportation of microplastics from soil to groundwater systems [45–50] which can lead to significant consequences when groundwater is used for drinking or agricultural purposes.

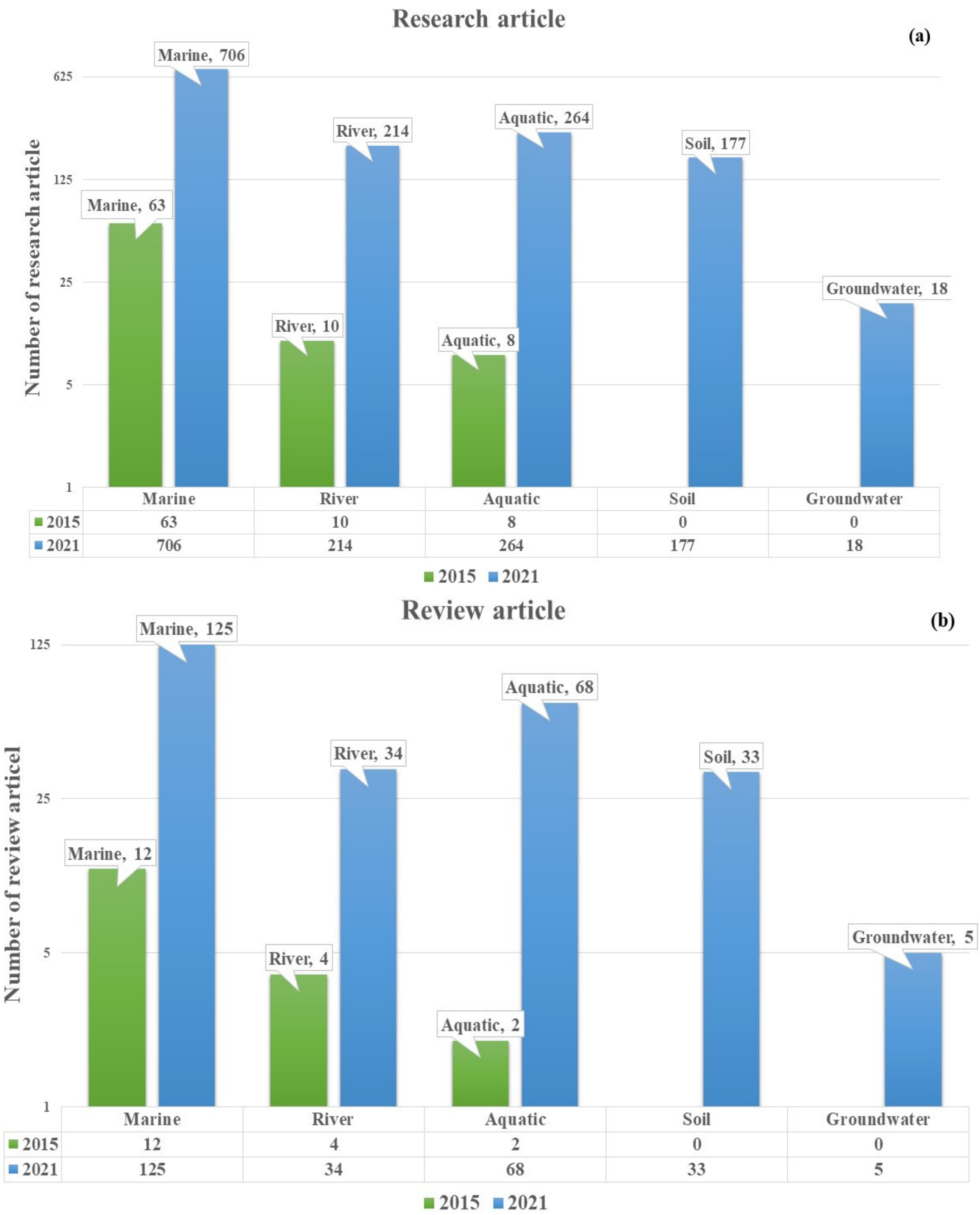

Figure 3. Articles on microplastics in different environments from 2015–2021, (**a**) research and (**b**) review microplastic articles (Source: web of science; search word: microplastic in marine, river, aquatic, soil, and groundwater).

Although groundwater pollution can affect human health [51,52], plant species, and underground microorganisms, there are considerably fewer studies on microplastics in groundwater than in soils. Microplastics in groundwater should not be underestimated. They necessitate urgent attention from the scientific community, especially hydrogeology and environmental impact studies, to decrease their negative impact and to estimate their potential threats to the environment and human society. The purpose of this review is to (1) highlight the gaps and challenges in the current literature on microplastic pollution and sources in groundwater, and (2) describe and discuss strategies for the management of microplastic contamination in groundwater systems in the future.

2. Current Issues in Microplastic Pollution Occurrences and Sources in Groundwater

The horizontal and vertical transportation of microplastics from soil migration, surface runoff from mulching waste, and industrialization and urbanization can lead to the contamination of groundwater systems with microplastics. Groundwater can also be contaminated with several toxic materials and contaminants from anthropogenic activities [53], thereby placing groundwater resources at risk [54,55]. Notably, groundwater is used in approximately 38% of agricultural and cultivated areas globally [56]. The invisible nature of groundwater makes it difficult to observe and maintain [1]. Groundwater samples from Chennai, India, were reported to contain fibrous and fragment-shaped microplastics [57]. When synthetic microfibers are too small to be filtered by wastewater treatment plants (WWTPs), they can leach into soil via land-applied WWTP's biosolids [38,58–60] (Figure 4) and/or may directly be dispensed as grey water out of a septic tank, creating a conduit for microfibers to infiltrate groundwater systems [1,61]. Median and maximum concentrations of microplastics (microfibers) measuring 6.4 and 15.2 n/L, respectively, were observed in a karst groundwater aquifer system [2]. A low concentration of microplastics measuring 0.0007 n/L was reported in Holdorf, Germany, which was smaller than other microplastic concentrations observed in groundwater around the world [3]. In an alluvial sedimentary unconfined aquifer area (agricultural area), groundwater was found to be contaminated with microplastics with a concentration of 38 ± 8 n/L [5]. Groundwater contamination with microplastics [62] and numerous metals, such as Pb, Cu, Cd, As, Zn, and Mn, has been linked with landfills [63] at Chennai and Tamil Nadu, India. These investigations constitute the most recent contributions to the knowledge on groundwater contamination with microplastics, and distribution comments and remarks have been made and published for those investigations [64,65]. The above studies have provided data indicating that research on groundwater should receive international attention.

Therefore, qualifying and quantifying microplastics in groundwater may require a multi-pronged strategy with careful sampling methods and alternative approaches, making it more complicated than studies of other freshwater environments [66]. There have been a few published research and review papers on groundwater contamination with microplastics (Table 1). Some of these studies related the problem with soil pollution and determined that soil acts as a potential conduit for microplastics to enter groundwater systems [45,67–69]. There is a possibility that microplastics can reach groundwater situated below agricultural or cultivated land [50] The two most common transport systems are horizontal and vertical transportation [70]; horizontal transport of microplastic in soil mostly occurs via surface runoff and wind erosion [44,71], whereas vertical transportation of microplastic in the soil is mainly influenced by microorganisms and earthworms, which increase the risk of microplastic contamination in groundwater systems [44,59].

PE and PET are the most common microplastic materials in groundwater pollution systems [3,5,69,72,73] and fragments and fibers are the most common shapes (Table 2). There are five main sources and causes of microplastics in groundwater: landfill leachate, soil migration, wastewater effluent, surface runoff from mulching waste [74], and human activities related to plastic usage and disposal [2,63,73,75]. When compared with groundwater microplastic contamination, the surface water contamination is considerably higher since it has directly been impacted and contaminated by anthropogenic activity (Figure 4). WWTPs and Sewage treatment plants (STPs) serve as pathways for microplastics to enter the surface water when such water sources are located near the WWTP and STP areas [76,77]. PE, polypropylene (PP), and polystyrene (PS) are the most abundant types found in the surface water, and fragments, fibers, and films are mostly common shapes [77,78]. Unlike in groundwater, PET is not abundant in surface water because the density of PET is higher than that of the surface water [79].

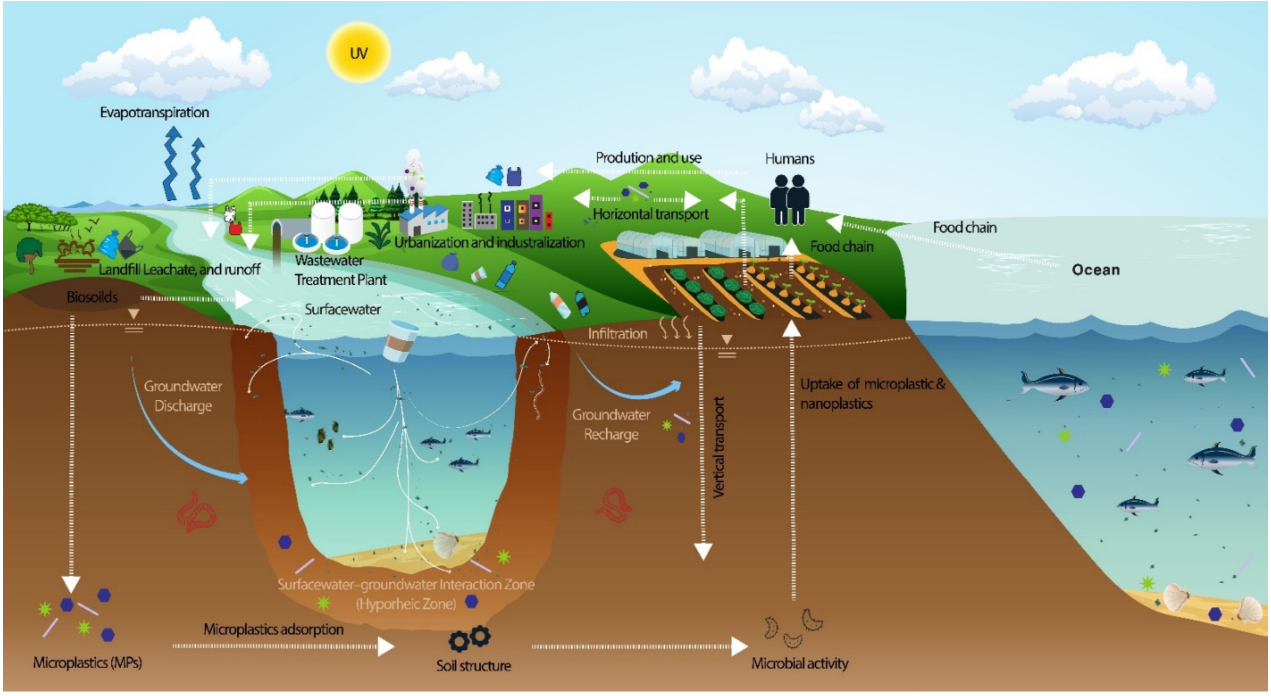

Figure 4. Potential microplastic occurrences and sources for entrance and transport into the subsurface water and groundwater environment. Adapted from [66].

Table 1. Recent research on microplastics in groundwater and soil.

Study (Author)	Study Title
[1]	Addressing the potential for groundwater contamination by plastic microfibers
[4]	Existence of microplastics in soil and groundwater in Jiaodong Peninsula
[73]	Microplastic pollution in soils and groundwater: Characteristics, analytical methods, and impacts
[80]	Microplastics in the environment: A critical review of current understanding and identification of future research needs
[62]	Spatial distribution of microplastic concentration around landfill sites and its potential risk on groundwater
[5]	Microplastic contamination of an unconfined groundwater aquifer in Victoria, Australia
[81]	Microplastics in the soil-groundwater environment: Aging, migration, and co-transport of contaminants (review)
[82]	Heavy metal remediation by nano zero-valent iron in the presence of microplastics in groundwater
[66]	Emerging concerns about Microplastics Pollution on Groundwater in South Korea
[45]	Microplastic pollution in soil and groundwater (review)
[57]	Microplastics Pollution Pathways to Groundwater in India
[2]	Microplastic Contamination in Karst Groundwater Systems
[63]	Hazardous microplastic characteristics and its role as a vector of heavy metal in groundwater and surface water of coastal south India

Table 1. *Cont.*

Study (Author)	Study Title
[83]	Assessment of Causes and Effects of Groundwater Level Change in an Urban Area (Warsaw, Poland)
[50]	Plastic in agricultural soils; A global risk for groundwater systems and drinking water supplies (review)
[3]	Low numbers of microplastics detected in drinking water from ground water sources
[84]	The occurrence of microplastics in freshwater systems—preliminary results from Krakow (Poland)
[85]	Fate and transport of microplastics from water sources
[86]	Identification and Quantification of Microplastics in Potable Water and Their Sources within Water Treatment Works in England and Wales
[87]	Mapping Microplastic in Norwegian Drinking Water, Atlantic
[88]	Analysis of microplastic particles in Danish drinking water
[89]	Metro station free drinking water fountain—A potential "microplastics hotspot" for human consumption
[90]	Drinking plastics?—Quantification and qualification of microplastics in drinking water distribution systems by µFTIR and Py-GCMS
[72]	Investigation of microplastic contamination in drinking water from a German city

Landfill leachates are mainly responsible for heavy and hazardous metal contamination in groundwater systems [63,91,92]. Microplastics can absorb persistent organic pollutants and metals and may act as a transporter of these hazardous substances in the subsurface water, soil, and/or groundwater [44,84,93]. The leachate pollution index [94] related to groundwater contamination presents a gap in the research and should be investigated in the future. Washing clothes made from synthetic materials can produce microfibers in the wastewater or septic tank effluent, which is a potential source of microplastics (microfibers) in the hyporheic zone, the zone between surface and groundwater [95] and groundwater systems [2,15,57,89].

Table 2. Typical occurrences and phenomenon of microplastic contamination in groundwater (Adapted from (Huang et al., 2021)).

Type	Depth	Concentration	Size	Major Shape	Polymer Type	Location	Reference
Deep well (untreated potable water)	nd	nd	0–0.045 mm	Fragments	nd	Krakow, Poland	[84]
Karst system	<65 m	15.2 n/L(max)	<1.5 mm	Fibers	PE	Illinois, USA	[2]
not mentioned	nd	5.3 (4–7) n/L	nd	Fragments and fibers	PET and PA	Tamil Nadu, India	[85]
Drinking water	2–29 m	38 ± 8 n/L	18–491 µm	Fragments and fibers	PE, PS, PP, PVC, PET, PC, PMMA, and PA	Victoria, Australia	[5]
Well	30 m	0.0007 n/L	0.05–0.15 mm	Fragments	PE	Holdorf, Germany	[3]
Wells & borewells	2–5 m	4.2 n/L (median), 10.1 n/L (max)	0.11–12.5 mm (mean: 0.6 ± 1.4 mm), <1 mm (34% domain)	Fibers, foam, pellets, films, and fragments	Nylon (PA, 35%), PE (55%) and PET (10%)	Tamil Nadu, India	[63]

Table 2. *Cont.*

Type	Depth	Concentration	Size	Major Shape	Polymer Type	Location	Reference
Landfills (municipal solid waste disposal sites)	3–30.48 m	2–80 n/L	nd	Pellets, foam, fragments, and fibers	Nylon, PVC, and PE	Chennai, India	[62]
Tap (Treated portable water)	nd	0–0.011 n/L (>LOD), 0–0.003 n/L (>LOQ)	>0.025 mm	nd	ABS and PS (domain, >LOQ)	England & Wales, UK	[86]
Tap	nd	<1 n/L (below LOD)	>0.1 mm	nd	nd	Norway	[87]
Estuary	2–5 m	4.2 n/L	0.11–12.5 mm (mean: 0.6 ± 1.4 mm)	Fibers, foam, film, and fragments	Nylon, PP, PVC, and PE	Punakayal, India	[63]
Tap (Treated potable water)	nd	<1 n/L	>0.01 mm	Fragments and fibers	PET, PP, PS, and PE	Rüsselsheim, Germany	[72]
Tap	nd	0.3 n/L	<0.3 mm	Fibers, fragments, and films	PET, PP, PS, ABS, and PU	Denmark	[88]
Public drinking water fountains	nd	18 ± 7 n/L	0.5–5 mm (50%); <0.5 mm (50%)	Fibers and fragments	PTT and epoxy resin	Mexico City, Mexico	[89]
Drinking water	nd	0.174 n/L	<0.15 mm (32% <0.02 mm)	Fibers and fragments	PA, PET, and acrylates	Skåne, Sweden	[90]

Notes: PVC, polyvinyl chloride; PA, polyamide; PE, polyethylene; PS, polystyrene; PP, polypropylene; PU, polyurethane; PET, polyethylene terephthalate; ABS, acrylonitrile butadiene styrene; PTT, polytrimethylene terephthalate; PMMA, polymethylmethacrylate; LOD, limit of detection; LOQ, limit of quantification; nd, not described.

3. Effect of Groundwater Microplastics on Health of Humans, Plants, and Other Species

There has been almost no research on the impacts and effects of groundwater microplastic contamination [45,96]. This reveals a major gap in the research that needs to be filled in the future. To reach the groundwater, microplastics need to be smaller than soil pores, as this allows them to pass through the soil layers [49,81,97–99], which indicates the degradation of larger plastic waste that is buried in soil [100]. Soils contain macropores (>0.08 mm) and micropores (<0.08 mm) which drive cracks, fissures, and fractures [101]. Some external factors such as earthquakes and liquefaction can also play a vital role in shaking down the soil pores. This creates new paths in the groundwater system, posing a hazard. Additionally, if the soil layer is too shallow and the groundwater level is high, there is a higher chance that microplastic can pass the soil horizon and enter the groundwater environments easily. Drinking water from groundwater contaminated with smaller microplastic particles is a major issue [102,103]. Although the direct effects of groundwater microplastics on human health have not been studied, there is evidence that microplastics bear adverse effects on humans, such as contributing to cardiovascular diseases, skin irritation, cancer, reproductive effects, and respiratory and digestive problems [61,104–109].

Research on the effects of microplastics on plants is still in its infancy [73]. According to P. Wanner [50], microplastics are more likely to reach groundwater below farmland or agricultural land. The potential uptake routes mostly occur through the soil and in some farmlands, by the plant roots. Exposing crops to microplastic contaminated groundwater could trigger microplastic uptake throughout plant roots or a change in soil characteristics, both of which could impact plant development [62,110]. Microplastic uptake by microbial activity and plant roots pose a hazard to edible plants (Figure 4) and can eventually be distributed up the food chain system [111]. Groundwater contaminated with microplastics is dangerous for use as drinking water or in agricultural processes for human health and is more dangerous than consuming contaminated seafood and fish [1]. In the case of agricultural processes, a microplastic waste cycling system can be developed if groundwater contaminated from the vertical transport of microplastics is used for agricultural and cultivated land. The increase in microplastic contamination in groundwater can impose a destructive effect on groundwater microorganisms. There are several unique faunas in groundwater, such as troglofaunal [112–116] and stygofauna [73], which could be vulnerable to microplastic contamination. However, the exact mechanism underlying how groundwater microplastics affect such faunal species remains unknown and requires additional research.

4. Strategies for Groundwater Microplastic Management

The study of microplastic contamination in groundwater and strategies for groundwater microplastic management are in the early stages. Reports of groundwater contaminated with heavy metals, arsenic, fluoride, chloride (salinization), coliform bacteria, pesticides, petrochemicals, nitrates, light non-aqueous phase liquids (LNAPL), dense non-aqueous phase liquids (DNAPL), pathogens, and volatile organic compounds (VOCs) [117,118] surfaced prior to the issue of microplastic pollution emerging. Now, this too poses a serious threat to human health and natural environments as with the other pollutants [45]. Strategies to manage microplastic pollution in groundwater should focus on three main factors: (1) preventive measures and developing national and international rules and regulations, (2) remediation of microplastics that have entered groundwater, and (3) increasing social awareness and encouraging the usage of biodegradable plastics. To reduce the severity of microplastic contamination in groundwater, the quantity of contaminants from different sources needs to be controlled [44,119,120].

One example of prevention measures through national policy is the banning of cosmetic products that contain microplastic beads, which represented the major source of primary microplastics in the United States in 2017 [121]. At the same time, several countries in the EU have already banned or imposed taxes on plastic bags as an effort towards plastic reduction [122]. The EU have been implementing restrictions on the usage of both single and multiple-use plastic bags with various strategies depending on the country [121,123]. By 2030, Europe aims to recycle more than half of all plastic waste. All plastic packaging will be reusable or recycled in order to reduce cost and to prevent microplastic [124]. According to Magnusson and Noren [125], microplastic is often found in the receiving water body from WWTPs, and thus, an initiative monitoring system is required. The United Nations launched 17 Sustainable Development Goals (SDGs) in 2015 to maintain human peace and prosperity, eradicate poverty, and safeguard the planet's resources for the future. Among the 17 SDGs, Goal 14 (Life Below Water) is the most relevant to microplastic pollution in the environment (mostly marine) [126]. Although no SDGs directly refer to microplastic contamination in groundwater, some SDGs relating to maintaining the health of aquifers are relevant to microplastic pollution management (Table 3). According to Sinreich [127], different groundwater contaminants, such as heavy metals, arsenic, nitrates, LNAPL, and microplastics, require different remediation methods. There have been no recent studies on the remediation of groundwater microplastic; however, the mitigation of microplastics and other contaminants from groundwater has been studied [121,128–130]. The mitigation of microplastics in groundwater plays a vital role and should be carried out before remediation. Additionally, the mitigation of microplastics from soil and surface water is also helpful in mitigating and resolving microplastic contamination in groundwater systems [45,118,131]. Future research should focus on the remediation of microplastics in groundwater. Another strategy for the management of microplastics in groundwater is using biodegradable plastic material that can be completely degraded either anaerobically or aerobically in the environment [98,132]. The impact of which biodegradable plastic can have on hydrological environments and marine species remains a controversial topic [133,134]. However, microplastics in the soil can be reduced by using biodegradable plastic in agricultural or cultivated lands [47]. Therefore, using biodegradable plastic can help reduce the potential impact of microplastics on groundwater indirectly since the soil can provide a potential pathway for microplastics to enter the groundwater environment. Biodegradable plastic will continue to have an undeniable and favorable influence on applications that are likely to end up in the environment [132,135]. It is also necessary to develop organized and systematic methods, protocols, and strategies for reducing microplastic contamination in groundwater through local and international governments and/or agencies.

Table 3. Interlinkage of the Sustainable Development Goals and the Groundwater Microplastic Contamination Issue.

Goal Number	Link between SDG and the Groundwater Microplastic Contamination	Rank (1–5) of Relevance to Microplastic Pollution in Groundwater
3 GOOD HEALTH AND WELL-BEING	Drinking groundwater contaminated by microplastics could have negative effects on human health and well-being [68,136].	4
6 CLEAN WATER AND SANITATION	Microplastics can be present even in 'clean' drinking water and treated wastewater effluent [137,138] and can thus harm the goal for clean water and sanitation.	3
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	The irresponsible production and consumption of plastic can be a big threat to the environment and increase the chance of microplastic contamination in groundwater [139].	5
14 LIFE BELOW WATER	Enormous amounts of microplastic are entering marine and freshwater ecosystems and damaging those environments, including groundwater habitats [22,31,33,140].	1
15 LIFE ON LAND	Terrestrial microplastic pollution, such as in landfills and agricultural soils, affects terrestrial life and can contaminate groundwater as soil is a potential pathway for the vertical transportation of microplastic [45–47].	2

5. Conclusions

Microplastic contamination is likely to persist for a long time due to the increasing production and use of plastics worldwide and a lack of efficient plastic waste management systems. It is expected that the study of microplastic contamination in groundwater will continue to grow owing to the susceptibility of groundwater resources to anthropogenic pressure, the critical role of groundwater in maintaining human activities and natural ecosystems, and since groundwater conservation and management measures are urgently required [1]. The negative impacts of microplastics on the environment, humans, and other species are increasing and extensive studies are required to fully comprehend the incidence, fate, and movement of microplastics in groundwater systems. The problem of microplastics in groundwater is currently in an emerging stage but is steadily growing. This review presents recent and emerging knowledge on microplastic contamination in groundwater. Further research is needed to fill and address key gaps in knowledge, which we identified as follows:

- More studies are needed to determine the effects of groundwater microplastic contamination on the human body and microorganisms, such as stygofauna and troglofaunal, that inhabit groundwater environments.
- Systematic reports and investigations of potential groundwater microplastic contamination with careful sample collection should be carried out in Korea and other developed countries using advanced technology and instruments, such as Raman spectroscopy, Fourier transform infrared spectroscopy, and gas chromatography–mass spectroscopy, in the near future.
- Landfill leachates and surface runoff are among the main factors responsible for groundwater microplastic pollution. The leachate pollution index relationship with groundwater contamination represents a gap that needs to be addressed in the future.
- Studies should consider the involvement and links between microplastic contamination in groundwater and SDGs and encourage the United Nations to focus on this problem more closely in their future goals as groundwater is used as drinking water and for agricultural purposes.
- Since soil and surface water are the main potential pathways for microplastics to enter groundwater, further detailed research on the fate of microplastics and the occurrence in different horizons of soil should be conducted. In particular, the study of microplastics in the hyporheic zone, which is the area of contact between surface water and groundwater, will help to understand problems in groundwater.
- Whether microplastics play a role in the transportation of heavy metals into groundwater systems should be investigated to protect groundwater environments.
- In groundwater, PE and PET microfibers and fragments are the most common microplastics; therefore, specific remediation and mitigation strategies for these are needed.

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References

1. Re, V. Shedding light on the invisible: Addressing the potential for groundwater contamination by plastic microfibers. *Hydrogeol. J.* **2019**, *27*, 2719–2727. [CrossRef]
2. Panno, S.V.; Kelly, W.R.; Scott, J.; Zheng, W.; McNeish, R.E.; Holm, N.; Hoellein, T.J.; Baranski, E.L. Microplastic contamination in karst groundwater systems. *Groundwater* **2019**, *57*, 189–196. [CrossRef]
3. Mintenig, S.M.; Löder, M.G.J.; Primpke, S.; Gerdts, G. Low numbers of microplastics detected in drinking water from ground water sources. *Sci. Total Environ.* **2019**, *648*, 631–635. [CrossRef]
4. Su, S.; Zhou, S.; Lin, G. Existence of microplastics in soil and groundwater in Jiaodong Peninsula. In *E3S Web of Conferences*; EDP Sciences: Les Ulis, France, 2021; Volume 251. [CrossRef]
5. Samandra, S.; Johnston, J.M.; Jaeger, J.E.; Symons, B.; Xie, S.; Currell, M.; Ellis, A.V.; Clarke, B.O. Microplastic contamination of an unconfined groundwater aquifer in Victoria, Australia. *Sci. Total Environ.* **2022**, *802*, 149727. [CrossRef] [PubMed]
6. Plastics Europe. Plastics-the Facts 2020. An Analysis of European Plastics Production, Demand and Waste Data. 2020. Available online: https://plasticseurope.org/knowledge-hub/plastics-the-facts-2020/ (accessed on 11 February 2022).
7. Napper, I.E.; Thompson, R.C. Plastic debris in the marine environment: History and future challenges. *Glob. Chall.* **2020**, *4*, 1900081. [CrossRef]
8. Thompson, R.C.; Moore, C.J.; Vom Saal, F.S.; Swan, S.H. Plastics, the environment and human health: Current consensus and future trends. *Philos. Trans. R. Soc. B Biol. Sci.* **2009**, *364*, 2153–2166. [CrossRef]
9. Nanda, S.; Berruti, F. Thermochemical conversion of plastic waste to fuels: A review. *Environ. Chem. Lett.* **2021**, *19*, 123–148. [CrossRef]
10. Chico-Ortiz, N.; Mahu, E.; Crane, R.; Gordon, C.; Marchant, R. Microplastics in Ghanaian coastal lagoon sediments: Their occurrence and spatial distribution. *Reg. Stud. Mar. Sci.* **2020**, *40*, 101509. [CrossRef]
11. Banu, J.R.; Sharmila, V.G.; Ushani, U.; Amudha, V.; Kumar, G. Impervious and influence in the liquid fuel production from municipal plastic waste through thermo-chemical biomass conversion technologies—A review. *Sci. Total Environ.* **2020**, *718*, 137287. [CrossRef]
12. Bajt, O. From plastics to microplastics and organisms. *FEBS Open Bio* **2021**, *11*, 954–966. [CrossRef]
13. Thompson, R.C.; Olsen, Y.; Mitchell, R.P.; Davis, A.; Rowland, S.J.; John, A.W.; McGonigle, D.; Russell, A.E. Lost at sea: Where is all the plastic? *Science* **2004**, *304*, 838. [CrossRef]
14. Arthur, C.; Baker, J.; Bamford, H. *Proceedings of the International Research Workshop on the Occurrence, Effects, and Fate of Microplastic Marine Debris*; NOAA Technical Memorandum NOSOR&R-30; NOAA: Silver Spring, MD, USA, 2009; p. 49. Available online: www.MarineDebris.noaa.gov (accessed on 15 December 2021).
15. Browne, M.A.; Crump, P.; Niven, S.J.; Teuten, E.; Tonkin, A.; Galloway, T.; Thompson, R. Accumulation of microplastic on shorelines woldwide: Sources and sinks. *Environ. Sci. Technol.* **2011**, *45*, 9175–9179. [CrossRef]
16. Fendall, L.S.; Sewell, M.A. Contributing to marine pollution by washing your face: Microplastics in facial cleansers. *Mar. Pollut. Bull.* **2009**, *58*, 1225–1228. [CrossRef] [PubMed]
17. Gregory, M.R. Plastic 'scrubbers' in hand cleansers: A further (and minor) source for marine pollution identified. *Mar. Pollut. Bull.* **1996**, *32*, 867–871. [CrossRef]
18. Geogory, M.R.; Andrady, L.A. Plastic in the Marine Environment. In *Plastics and the Environment*; Wiley-Interscience: Hoboken, NJ, USA, 2003. Available online: https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=PLASTICS+IN+THE+MARINE+ENVIRONMENT+MURRAY+R.+GREGORY+Department+of+Geology%2C+The+University+of+Auckland+ANTHONY+L.+ANDRADY+Research+Triangle+Institut&btnG= (accessed on 15 December 2021).
19. Da Costa, J.P.; Nunes, A.R.; Santos, P.S.; Girao, A.V.; Duarte, A.C.; Rocha-Santos, T. Degradation of polyethylene microplastics in seawater: Insights into the environmental degradation of polymers. *J. Environ. Sci. Health Part A* **2018**, *53*, 866–875. [CrossRef]
20. Ajith, N.; Arumugam, S.; Parthasarathy, S.; Manupoori, S.; Janakiraman, S. Global distribution of microplastics and its impact on marine environment—A review. *Environ. Sci. Pollut. Res.* **2020**, *27*, 25970–25986. [CrossRef]
21. Mattsson, K.; Jocic, S.; Doverbratt, I.; Hansson, L.A. Nanoplastics in the Aquatic Environment. In *Microplastic Contamination in Aquatic Environments: An Emerging Matter of Environmental Urgency*; Elsevier Inc.: Gothenburg, Sweden, 2018; pp. 379–399. [CrossRef]
22. Tibbetts, J.; Krause, S.; Lynch, I.; Sambrook Smith, G.H. Abundance, distribution, and drivers of microplastic contamination in urban river environments. *Water* **2018**, *10*, 1597. [CrossRef]
23. Hohn, S.; Acevedo-Trejos, E.; Abrams, J.F.; de Moura, J.F.; Spranz, R.; Merico, A. The long-term legacy of plastic mass production. *Sci. Total Environ.* **2020**, *746*, 141115. [CrossRef]
24. Geyer, R.; Jambeck, J.R.; Law, K.L. Production, Use, and Fate of All Plastics Ever Made. 2017. Available online: https://www.science.org (accessed on 16 December 2021).
25. Iñiguez, M.E.; Conesa, J.A.; Fullana, A. Microplastics in Spanish table salt. *Sci. Rep.* **2017**, *7*, 8620. [CrossRef]
26. Kosuth, M.; Mason, S.A.; Wattenberg, E.V. Anthropogenic contamination of tap water, beer, and sea salt. *PLoS ONE* **2018**, *13*, e0194970. [CrossRef]
27. Hurley, R.; Woodward, J.; Rothwell, J.J. Microplastic contamination of river beds significantly reduced by catchment-wide flooding. *Nat. Geosci.* **2018**, *11*, 251–257. [CrossRef]
28. Klein, S.; Worch, E.; Knepper, T.P. Occurrence and spatial distribution of microplastics in river shore sediments of the Rhine-Main area in Germany. *Environ. Sci. Technol.* **2015**, *49*, 6070–6076. [CrossRef]

29. Lechner, A.; Keckeis, H.; Lumesberger-Loisl, F.; Zens, B.; Krusch, R.; Tritthart, M.; Glas, M.; Schludermann, E. The Danube so colourful: A potpourri of plastic litter outnumbers fish larvae in Europe's second largest river. *Environ. Pollut.* **2014**, *188*, 177–181. [CrossRef]
30. Lechner, A.; Ramler, D. The discharge of certain amounts of industrial microplastic from a production plant into the River Danube is permitted by the Austrian legislation. *Environ. Pollut.* **2015**, *200*, 159–160. [CrossRef]
31. Alimi, O.S.; Farner Budarz, J.; Hernandez, L.M.; Tufenkji, N. Microplastics and nanoplastics in aquatic environments: Aggregation, deposition, and enhanced contaminant transport. *Environ. Sci. Technol.* **2018**, *52*, 1704–1724. [CrossRef] [PubMed]
32. Wright, S.L.; Thompson, R.C.; Galloway, T.S. The physical impacts of microplastics on marine organisms: A review. *Environ. Pollut.* **2013**, *178*, 483–492. [CrossRef]
33. Sharma, S.; Chatterjee, S. Microplastic pollution, a threat to marine ecosystem and human health: A short review. *Environ. Sci. Pollut. Res.* **2017**, *24*, 21530–21547. [CrossRef]
34. Andrady, A.L. Microplastics in the marine environment. *Mar. Pollut. Bull.* **2011**, *62*, 1596–1605. [CrossRef]
35. Geissen, V.; Mol, H.; Klumpp, E.; Umlauf, G.; Nadal, M.; Van der Ploeg, M.; Van de Zee, S.E.; Ritsema, C.J. Emerging pollutants in the environment: A challenge for water resource management. *Int. Soil Water Conserv. Res.* **2015**, *3*, 57–65. [CrossRef]
36. Avio, C.G.; Gorbi, S.; Regoli, F. Plastics and microplastics in the oceans: From emerging pollutants to emerged threat. *Mar. Environ. Res.* **2017**, *128*, 2–11. [CrossRef]
37. Da Costa, J.P.; Duarte, A.C.; Rocha-Santos, T. *The Environmental Impacts of Plastics and Micro-Plastics Use, Waste and Pollution: EU and National Measures*; European Parliament: Strasbourg, France, 2020.
38. Rillig, M.C. Microplastic in Terrestrial Ecosystems and the Soil? *Environ. Sci. Technol.* **2012**, *46*, 6453–6454. [CrossRef] [PubMed]
39. Crossman, J.; Hurley, R.R.; Futter, M.; Nizzetto, L. Transfer and transport of microplastics from biosolids to agricultural soils and the wider environment. *Sci. Total Environ.* **2020**, *724*, 138334. [CrossRef] [PubMed]
40. David, J.; Weissmannová, H.D.; Steinmetz, Z.; Kabelíková, L.; Demyan, M.S.; Šimečková, J.; Tokarski, D.; Siewert, C.; Schaumann, G.E.; Kučerík, J. Introducing a soil universal model method (SUMM) and its application for qualitative and quantitative determination of poly (ethylene), poly (styrene), poly (vinyl chloride) and poly (ethylene terephthalate) microplastics in a model soil. *Chemosphere* **2019**, *225*, 810–819. [CrossRef] [PubMed]
41. Qian, Z.; Zhang, H.; Yang, Z.; Yuan, L.I.; Yong, X.U.E.; ChuanCheng, F.U.; Chen, T.U.; YongMing, L.U.O. Separation of microplastics from a coastal soil and their surface microscopic features. *Chin. Sci. Bull.* **2016**, *61*, 1604–1611. [CrossRef]
42. Büks, F.; Kaupenjohann, M. Global concentrations of microplastics in soils—A review. *Soil* **2020**, *6*, 649–662. [CrossRef]
43. Weber, C.J.; Weihrauch, C.; Opp, C.; Chifflard, P. Investigating microplastic dynamics in soils: Orientation for sampling strategies and sample pre-procession. *Land Degrad. Dev.* **2021**, *32*, 270–284. [CrossRef]
44. O'Kelly, B.C.; El-Zein, A.; Liu, X.; Patel, A.; Fei, X.; Sharma, S.; Mohammad, A.; Goli, V.S.N.S.; Wang, J.J.; Li, D.; et al. Microplastics in soils: An environmental geotechnics perspective. *Environ. Geotech.* **2021**, *8*, 586–618. [CrossRef]
45. Chia, R.W.; Lee, J.Y.; Kim, H.; Jang, J. Microplastic pollution in soil and groundwater: A review. *Environ. Chem. Lett.* **2021**, *19*, 4211–4224. [CrossRef]
46. Zhou, B.; Wang, J.; Zhang, H.; Shi, H.; Fei, Y.; Huang, S.; Tong, Y.; Wen, D.; Luo, Y.; Barceló, D. Microplastics in agricultural soils on the coastal plain of Hangzhou Bay, east China: Multiple sources other than plastic mulching film. *J. Hazard. Mater.* **2020**, *388*, 121814. [CrossRef]
47. Guo, J.J.; Huang, X.P.; Xiang, L.; Wang, Y.Z.; Li, Y.W.; Li, H.; Cai, Q.Y.; Mo, C.H.; Wong, M.H. Source, migration and toxicology of microplastics in soil. *Environ. Int.* **2020**, *137*, 105263. [CrossRef]
48. Chae, Y.; An, Y.J. Current research trends on plastic pollution and ecological impacts on the soil ecosystem: A review. *Environ. Pollut.* **2018**, *240*, 387–395. [CrossRef] [PubMed]
49. Bläsing, M.; Amelung, W. Plastics in soil: Analytical methods and possible sources. *Sci. Total Environ.* **2018**, *612*, 422–435. [CrossRef]
50. Wanner, P. Plastic in agricultural soils—A global risk for groundwater systems and drinking water supplies?—A review. *Chemosphere* **2021**, *264*, 128453. [CrossRef] [PubMed]
51. Mehdi, S.E.H.; Amen, R.; Ali, A.; Anjum, H.; Mahmood, A.; Mubashir, M.; Mukhtar, A.; Ullah, S.; Al-Sehemi, A.G.; Ibrahim, M.; et al. Sources, chemistry, bioremediation and social aspects of arsenic-contaminated waters: A review. *Environ. Chem. Lett.* **2021**, *19*, 3859–3886. [CrossRef]
52. Redwan, M.; Moneim, A.A.A.; Mohammed, N.E.; Masoud, A.M. Sources and health risk assessments of nitrate in groundwater, West of Tahta area, Sohag, Egypt. *Epis. J. Int. Geosci.* **2020**, *43*, 751–760. [CrossRef]
53. Lapworth, D.J.; Baran, N.; Stuart, M.E.; Ward, R.S. Emerging organic contaminants in groundwater: A review of sources, fate and occurrence. *Environ. Pollut.* **2012**, *163*, 287–303. [CrossRef]
54. Prasad, B.; Sangita, K. Heavy metal pollution index of ground water of an abandoned open cast mine filled with fly ash: A case study. *Mine Water Environ.* **2008**, *27*, 265–267. [CrossRef]
55. Erostate, M.; Huneau, F.; Garel, E.; Ghiotti, S.; Vystavna, Y.; Garrido, M.; Pasqualini, V. Groundwater dependent ecosystems in coastal Mediterranean regions: Characterization, challenges and management for their protection. *Water Res.* **2020**, *172*, 115461. [CrossRef] [PubMed]

56. Siebert, S.; Henrich, V.; Frenken, K.; Burke, J. *Update of the Digital Global Map of Irrigation Areas to Version 5 DOCUMENTATION*; Technical Report; Rheinische Friedrich-Wilhelms-Universität: Bonn, Germany; Food and Agriculture Organization of the United Nations: Rome, Italy, 2013; Volume 7, pp. 1–172.
57. Kumar, R.; Sharma, P. Microplastics Pollution Pathways to Groundwater in India. 2021. Available online: https://www.researchgate.net/publication/348008657 (accessed on 3 January 2022).
58. Habib, D.; Locke, D.C.; Cannone, L.J. Synthetic fibers as indicators of municipal sewage sludge, sludge products, and sewage treatment plant effluents. *Water Air Soil Pollut.* **1998**, *103*, 1–8. [CrossRef]
59. Murphy, F.; Ewins, C.; Carbonnier, F.; Quinn, B. Wastewater treatment works (WwTW) as a source of microplastics in the aquatic environment. *Environ. Sci. Technol.* **2016**, *50*, 5800–5808. [CrossRef]
60. Zubris, K.A.V.; Richards, B.K. Synthetic fibers as an indicator of land application of sludge. *Environ. Pollut.* **2005**, *138*, 201–211. [CrossRef]
61. Hurley, R.R.; Nizzetto, L. Fate and occurrence of micro (nano) plastics in soils: Knowledge gaps and possible risks. *Curr. Opin. Environ. Sci. Health* **2018**, *1*, 6–11. [CrossRef]
62. Natesan, U.; Vaikunth, R.; Kumar, P.; Ruthra, R.; Srinivasalu, S. Spatial distribution of microplastic concentration around landfill sites and its potential risk on groundwater. *Chemosphere* **2021**, *277*, 130263. [CrossRef]
63. Selvam, S.; Jesuraja, K.; Venkatramanan, S.; Roy, P.D.; Kumari, V.J. Hazardous microplastic characteristics and its role as a vector of heavy metal in groundwater and surface water of coastal south India. *J. Hazard. Mater.* **2021**, *402*, 123786. [CrossRef] [PubMed]
64. Lee, J.Y.; Cha, J.; Jeong, E.; Kim, Y.I. Comment on "Spatial distribution of microplastic concentration around landfill sites and its potential risk on groundwater". *Chemosphere* **2021**, *284*, 131376. [CrossRef] [PubMed]
65. Jeong, E.; Lee, J.Y. Comment on "Hazardous microplastic characteristics and its role as a vector of heavy metal in groundwater and surface water of coastal south India". *J. Hazard. Mater.* **2022**, *421*, 126693. [CrossRef] [PubMed]
66. Kim, H.; Lee, J.Y. Emerging concerns about microplastic pollution on groundwater in South Korea. *Sustainability* **2020**, *12*, 5275. [CrossRef]
67. Yu, M.; Van Der Ploeg, M.; Lwanga, E.H.; Yang, X.; Zhang, S.; Ma, X.; Ritsema, C.J.; Geissen, V. Leaching of microplastics by preferential flow in earthworm (*Lumbricus terrestris*) burrows. *Environ. Chem.* **2019**, *16*, 31–40. [CrossRef]
68. Rillig, M.C.; Ingraffia, R.; de Souza Machado, A.A. Microplastic incorporation into soil in agroecosystems. *Front. Plant Sci.* **2017**, *8*, 1805. [CrossRef]
69. Rillig, M.C.; Ziersch, L.; Hempel, S. Microplastic transport in soil by earthworms. *Sci. Rep.* **2017**, *7*, 1362. [CrossRef]
70. Yu, Q.; Hu, X.; Yang, B.; Zhang, G.; Wang, J.; Ling, W. Distribution, abundance and risks of microplastics in the environment. *Chemosphere* **2020**, *249*, 126059. [CrossRef] [PubMed]
71. Li, J.; Song, Y.; Cai, Y. Focus topics on microplastics in soil: Analytical methods, occurrence, transport, and ecological risks. *Environ. Pollut.* **2020**, *257*, 113570. [CrossRef] [PubMed]
72. Weber, F.; Kerpen, J.; Wolff, S.; Langer, R.; Eschweiler, V. Investigation of microplastics contamination in drinking water of a German city. *Sci. Total Environ.* **2021**, *755*, 143421. [CrossRef]
73. Huang, J.; Chen, H.; Zheng, Y.; Yang, Y.; Zhang, Y.; Gao, B. Microplastic pollution in soils and groundwater: Characteristics, analytical methods and impacts. *Chem. Eng. J.* **2021**, *425*, 131870. [CrossRef]
74. Qadeer, A.; Ajmal, Z.; Usman, M.; Zhao, X.; Chang, S. Agricultural plastic mulching as a potential key source of microplastic pollution in the terrestrial ecosystem and consequences. *Resour. Conserv. Recycl.* **2021**, *175*, 105855. [CrossRef]
75. Singhal, G.; Bansod, B.; Mathew, L.; Goswami, J.; Choudhury, B.U.; Raju, P.L.N. Comparison of parametric and non-parametric methods for chlorophyll estimation based on high-resolution UAV imagery. *Curr. Sci.* **2019**, *117*, 1874–1879. [CrossRef]
76. Alvim, C.B.; Mendoza-Roca, J.A.; Bes-Piá, A. Wastewater treatment plant as microplastics release source–quantification and identification techniques. *J. Environ. Manag.* **2020**, *255*, 109739. [CrossRef]
77. Park, T.J.; Lee, S.H.; Lee, M.S.; Lee, J.K.; Park, J.H.; Zoh, K.D. Distributions of microplastics in surface water, fish, and sediment in the vicinity of a sewage treatment plant. *Water* **2020**, *12*, 3333. [CrossRef]
78. Sighicelli, M.; Pietrelli, L.; Lecce, F.; Iannilli, V.; Falconieri, M.; Coscia, L.; Di Vito, S.; Nuglio, S.; Zampetti, G. Microplastic pollution in the surface waters of Italian Subalpine Lakes. *Environ. Pollut.* **2018**, *236*, 645–651. [CrossRef] [PubMed]
79. Osorio, E.D.; Tanchuling, M.A.N.; Diola, M. Microplastics occurrence in surface waters and sediments in five river mouths of Manila Bay. *Front. Environ. Sci.* **2021**, *9*, 364. [CrossRef]
80. Akdogan, Z.; Guven, B. Microplastics in the environment: A critical review of current understanding and identification of future research needs. *Environ. Pollut.* **2019**, *254*, 113011. [CrossRef]
81. Ren, Z.; Gui, X.; Xu, X.; Zhao, L.; Qiu, H.; Cao, X. Microplastics in the soil-groundwater environment: Aging, migration, and co-transport of contaminants—A critical review. *J. Hazard. Mater.* **2021**, *419*, 126455. [CrossRef] [PubMed]
82. Luo, Z.; Zhu, J.; Yu, L.; Yin, K. Heavy metal remediation by nano zero-valent iron in the presence of microplastics in groundwater: Inhibition and induced promotion on aging effects. *Environ. Pollut.* **2021**, *287*, 117628. [CrossRef] [PubMed]
83. Krogulec, E.; Małecki, J.J.; Porowska, D.; Wojdalska, A. Assessment of causes and effects of groundwater level change in an urban area (Warsaw, Poland). *Water* **2020**, *12*, 3107. [CrossRef]
84. Połeć, M.; Aleksander-Kwaterczak, U.; Wątor, K.; Kmiecik, E. The occurrence of microplastics in freshwater systems—Preliminary results from Krakow (Poland). *Geol. Geophys. Environ.* **2018**, *44*, 391–400. [CrossRef]

85. Ganesan, M.; Nallathambi, G.; Srinivasalu, S. Fate and transport of microplastics from water sources. *Curr. Sci.* **2019**, *117*, 1879–1885. Available online: http://search.ebscohost.com/login.aspx?direct=true&profile=ehost&scope=site&authtype=crawler&jrnl=00113891&AN=140256441&h=u0gwOQTSM96WTFrtPHkwxvidEkn%2FKjaAVnJs8GNRLZ0eGsOWHOVTCuOSOenRqlOqtTvYL4l2ogM18uRJNhW6%2FA%3D%3D&crl=c (accessed on 10 February 2022). [CrossRef]
86. Johnson, A.C.; Ball, H.; Cross, R.; Horton, A.A.; Jurgens, M.D.; Read, D.S.; Vollertsen, J.; Svendsen, C. Identification and quantification of microplastics in potable water and their sources within water treatment works in England and Wales. *Environ. Sci. Technol.* **2020**, *54*, 12326–12334. [CrossRef] [PubMed]
87. Uhl, W.; Eftekhardadkhah, M.; Svendsen, C. Mapping Microplastic in Norwegian Drinking Water, Norsk Vann Report 241. 2018. Available online: https://www.researchgate.net/publication/328412920 (accessed on 10 February 2022).
88. Strand, J.; Feld, L.; Murphy, F.; Mackevica, A.; Hartmann, N.B. Analysis of Microplastic Particles in Danish Drinking Water. 2018. Available online: https://dce2.au.dk/pub/SR291.pdf (accessed on 10 February 2022).
89. Shruti, V.C.; Pérez-Guevara, F.; Kutralam-Muniasamy, G. Metro station free drinking water fountain—A potential "microplastics hotspot" for human consumption. *Environ. Pollut.* **2020**, *261*, 114227. [CrossRef]
90. Kirstein, I.V.; Hensel, F.; Gomiero, A.; Iordachescu, L.; Vianello, A.; Wittgren, H.B.; Vollertsen, J. Drinking plastics?—Quantification and qualification of microplastics in drinking water distribution systems by µFTIR and Py-GCMS. *Water Res.* **2021**, *188*, 116519. [CrossRef]
91. Christensen, T.H.; Kjeldsen, P.; Bjerg, P.L.; Jensen, D.L.; Christensen, J.B.; Baun, A.; Albrechtsen, H.J.; Heron, G. Biogeochemistry of landfill leachate plumes. *Appl. Geochem.* **2001**, *16*, 659–718. [CrossRef]
92. Mortula, M.M.; Atabay, S.; Fattah, K.P.; Madbuly, A. Leachability of microplastic from different plastic materials. *J. Environ. Manag.* **2021**, *294*, 112995. [CrossRef]
93. Hodson, M.E.; Duffus-Hodson, C.A.; Clark, A.; Prendergast-Miller, M.T.; Thorpe, K.L. Plastic bag derived-microplastics as a vector for metal exposure in terrestrial invertebrates. *Environ. Sci. Technol.* **2017**, *51*, 4714–4721. [CrossRef] [PubMed]
94. Kumar, D.; Alappat, B.J. Evaluating leachate contamination potential of landfill sites using leachate pollution index. *Clean Technol. Environ. Policy* **2005**, *7*, 190–197. [CrossRef]
95. Frei, S.; Piehl, S.; Gilfedder, B.S.; Löder, M.G.J.; Krutzke, J.; Wilhelm, L.; Laforsch, C. Occurence of microplastics in the hyporheic zone of rivers. *Sci. Rep.* **2019**, *9*, 15256. [CrossRef] [PubMed]
96. Qi, R.; Jones, D.L.; Li, Z.; Liu, Q.; Yan, C. Behavior of microplastics and plastic film residues in the soil environment: A critical review. *Sci. Total Environ.* **2020**, *703*, 134722. [CrossRef] [PubMed]
97. McGechan, M.B. SW—Soil and Water: Transport of Particulate and Colloid-sorbed Contaminants through Soil, Part 2: Trapping Processes and Soil Pore Geometry. *Biosyst. Eng.* **2002**, *83*, 387–395. [CrossRef]
98. Fahrenfeld, N.L.; Arbuckle-Keil, G.; Beni, N.N.; Bartelt-Hunt, S.L. Source tracking microplastics in the freshwater environment. *TrAC Trends Anal. Chem.* **2019**, *112*, 248–254. [CrossRef]
99. Cey, E.E.; Rudolph, D.L.; Passmore, J. Influence of macroporosity on preferential solute and colloid transport in unsaturated field soils. *J. Contam. Hydrol.* **2009**, *107*, 45–57. [CrossRef]
100. Abu-Rukah, Y.; Al-Kofahi, O. The assessment of the effect of landfill leachate on ground-water quality—A case study. El-Akader landfill site—North Jordan. *J. Arid Environ.* **2001**, *49*, 615–630. [CrossRef]
101. Pathan, S.I.; Arfaioli, P.; Bardelli, T.; Ceccherini, M.T.; Nannipieri, P.; Pietramellara, G. Soil pollution from micro- and nanoplastic debris: A hidden and unknown biohazard. *Sustainability* **2020**, *12*, 7255. [CrossRef]
102. Campanale, C.; Massarelli, C.; Savino, I.; Locaputo, V.; Uricchio, V.F. A detailed review study on potential effects of microplastics and additives of concern on human health. *Int. J. Environ. Res. Public Health* **2020**, *17*, 1212. [CrossRef] [PubMed]
103. Wang, L.; Wu, W.M.; Bolan, N.S.; Tsang, D.C.; Li, Y.; Qin, M.; Hou, D. Environmental fate, toxicity and risk management strategies of nanoplastics in the environment: Current status and future perspectives. *J. Hazard. Mater.* **2021**, *401*, 123415. [CrossRef] [PubMed]
104. Kurniawan, S.B.; Said, N.S.M.; Imron, M.F.; Abdullah, S.R.S. Microplastic pollution in the environment: Insights into emerging sources and potential threats. *Environ. Technol. Innov.* **2021**, *23*, 101790. [CrossRef]
105. He, P.; Chen, L.; Shao, L.; Zhang, H.; Lü, F. Municipal solid waste (MSW) landfill: A source of microplastics?—Evidence of microplastics in landfill leachate. *Water Res.* **2019**, *159*, 38–45. [CrossRef]
106. Rai, P.K.; Lee, J.; Brown, R.J.; Kim, K.H. Environmental fate, ecotoxicity biomarkers, and potential health effects of micro- and nano-scale plastic contamination. *J. Hazard. Mater.* **2021**, *403*, 123910. [CrossRef]
107. Sana, S.S.; Dogiparthi, L.K.; Gangadhar, L.; Chakravorty, A.; Abhishek, N. Effects of microplastics and nanoplastics on marine environment and human health. *Environ. Sci. Pollut. Res.* **2020**, *27*, 44743–44756. [CrossRef]
108. Smith, M.; Love, D.C.; Rochman, C.M.; Neff, R.A. Microplastics in seafood and the implications for human health. *Curr. Environ. Health Rep.* **2018**, *5*, 375–386. [CrossRef]
109. De-la-Torre, G.E. Microplastics: An emerging threat to food security and human health. *J. Food Sci. Technol.* **2019**, *57*, 1601–1608. [CrossRef]
110. de Souza Machado, A.A.; Lau, C.W.; Kloas, W.; Bergmann, J.; Bachelier, J.B.; Faltin, E.; Becker, R.; Görlich, A.S.; Rillig, M.C. Microplastics can change soil properties and affect plant performance. *Environ. Sci. Technol.* **2019**, *53*, 6044–6052. [CrossRef]

111. Igalavithana, A.D.; Mahagamage, M.G.Y.; Gajanayake, P.; Abeynayaka, A.; Gamaralalage, P.J.D.; Ohgaki, M.; Takenaka, M.; Fukai, T.; Itsubo, N. Microplastics and Potentially Toxic Elements: Potential Human Exposure Pathways through Agricultural Lands and Policy Based Countermeasures. *Microplastics* **2022**, *1*, 102–120. [CrossRef]
112. White, W.B. *Geomorphology and Hydrology of Karst Terrains*; Oxford University Press: New York, NY, USA, 1988. Available online: https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=112.%09White%2C+W.B.+Geomorphology+and+Hydrology+of+Karst+Terrains%3B+1988&btnG= (accessed on 24 January 2022).
113. Breitenbach, S. Breitenbach: Karst Hydrogeology and Geomorphology. 2008. Available online: https://scholar.google.com/scholar_lookup?title=Karst%20hydrogeology%20and%20geomorphology&publication_year=2008&author=S.%20Breitenbach (accessed on 24 January 2022).
114. Momot, O.; Synzynys, B.; Kozmin, G.; Silin, I. Pollution of ground sources of drinking water with technogenic tritium. In *Dangerous Pollutants (Xenobiotics) in Urban Water Cycle*; Springer: Dordrecht, The Netherlands, 2008; pp. 331–340. [CrossRef]
115. Bloom, A.L. Water-Formed Structures: Geomorphology and Hydrology of Karst Terrains. William B. White. Oxford University Press, New York, 1988. xiv, 464 pp., illus. $45. *Science* **1989**, *243*, 1618–1619. Available online: https://www.proquest.com/scholarly-journals/water-formed-structures-geomorphology-hydrology/docview/733242605/se-2?accountid=7411 (accessed on 24 January 2022). [CrossRef] [PubMed]
116. Oladoja, N.A.; Unuabonah, I.E. The pathways of microplastics contamination in raw and drinking water. *J. Water Process Eng.* **2021**, *41*, 102073. [CrossRef]
117. Kalhor, K.; Ghasemizadeh, R.; Rajic, L.; Alshawabkeh, A. Assessment of groundwater quality and remediation in karst aquifers: A review. *Groundw. Sustain. Dev.* **2019**, *8*, 104–121. [CrossRef] [PubMed]
118. Hara, K. Groundwater Contamination and Quality Management Policy in Asia. *Int. Rev. Environ. Strateg* **2006**, *6*, 291–306.
119. Pasalari, H.; Farzadkia, M.; Gholami, M.; Emamjomeh, M.M. Management of landfill leachate in Iran: Valorization, characteristics, and environmental approaches. *Environ. Chem. Lett.* **2019**, *17*, 335–348. [CrossRef]
120. Gunarathne, V.; Ashiq, A.; Ramanayaka, S.; Wijekoon, P.; Vithanage, M. Biochar from municipal solid waste for resource recovery and pollution remediation. *Environ. Chem. Lett.* **2019**, *17*, 1225–1235. [CrossRef]
121. Picó, Y.; Barceló, D. Analysis and prevention of microplastics pollution in water: Current perspectives and future directions. *ACS Omega* **2019**, *4*, 6709–6719. [CrossRef]
122. Convery, F.; McDonnell, S.; Ferreira, S. The most popular tax in Europe? Lessons from the Irish plastic bags levy. *Environ. Resour. Econ.* **2007**, *38*, 1–11. [CrossRef]
123. Steensgaard, I.M.; Syberg, K.; Rist, S.; Hartmann, N.B.; Boldrin, A.; Hansen, S.F. From macro-to microplastics-Analysis of EU regulation along the life cycle of plastic bags. *Environ. Pollut.* **2017**, *224*, 289–299. [CrossRef]
124. Foschi, E.; Bonoli, A. The commitment of packaging industry in the framework of the european strategy for plastics in a circular economy. *Adm. Sci.* **2019**, *9*, 18. [CrossRef]
125. Magnusson, K.; Noren, F. Screening of microplastic particles in and down-stream a wastewater treatment plant. *Swed. Environ. Res. Inst.* **2014**, *55*, 24. Available online: https://www.diva-portal.org/smash/record.jsf?pid=diva2%3A773505&dswid=-7132 (accessed on 16 February 2022).
126. Walker, T.R. (Micro) plastics and the UN sustainable development goals. *Curr. Opin. Green Sustain. Chem.* **2021**, *30*, 100497. [CrossRef]
127. Sinreich, M. Contaminant Attenuation in Karst Aquifers: A Paradigm Shift. In *H2Karst Research in Limestone Hydrogeology*; Springer International Publishing: Cham, Switzerland, 2014; pp. 175–184. [CrossRef]
128. Ni, B.J.; Zhu, Z.R.; Li, W.H.; Yan, X.; Wei, W.; Xu, Q.; Xia, Z.; Dai, X.; Sun, J. Microplastics mitigation in sewage sludge through pyrolysis: The role of pyrolysis temperature. *Environ. Sci. Technol. Lett.* **2020**, *7*, 961–967. [CrossRef]
129. Padervand, M.; Lichtfouse, E.; Robert, D.; Wang, C. Removal of microplastics from the environment. A review. *Environ. Chem. Lett.* **2020**, *18*, 807–828. [CrossRef]
130. Tofa, T.S.; Kunjali, K.L.; Paul, S.; Dutta, J. Visible light photocatalytic degradation of microplastic residues with zinc oxide nanorods. *Environ. Chem. Lett.* **2019**, *17*, 1341–1346. [CrossRef]
131. Fu, D.; Chen, C.M.; Qi, H.; Fan, Z.; Wang, Z.; Peng, L.; Li, B. Occurrences and distribution of microplastic pollution and the control measures in China. *Mar. Pollut. Bull.* **2020**, *153*, 110963. [CrossRef]
132. Paço, A.; Jacinto, J.; da Costa, J.P.; Santos, P.S.; Vitorino, R.; Duarte, A.C.; Rocha-Santos, T. Biotechnological tools for the effective management of plastics in the environment. *Crit. Rev. Environ. Sci. Technol.* **2019**, *49*, 410–441. [CrossRef]
133. Green, D.S.; Boots, B.; Sigwart, J.; Jiang, S.; Rocha, C. Effects of conventional and biodegradable microplastics on a marine ecosystem engineer (*Arenicola marina*) and sediment nutrient cycling. *Environ. Pollut.* **2016**, *208*, 426–434. [CrossRef]
134. Straub, S.; Hirsch, P.E.; Burkhardt-Holm, P. Biodegradable and Petroleum-Based Microplastics Do Not Differ in Their Ingestion and Excretion but in Their Biological Effects in a Freshwater Invertebrate *Gammarus fossarum*. *Int. J. Environ. Res. Public Health* **2017**, *14*, 774. [CrossRef]
135. Filiciotto, L.; Rothenberg, G. Biodegradable Plastics: Standards, Policies, and Impacts. *ChemSusChem* **2021**, *14*, 56–72. [CrossRef]
136. Koelmans, A.A.; Nor, N.H.M.; Hermsen, E.; Kooi, M.; Mintenig, S.M.; De France, J. Microplastics in freshwaters and drinking water: Critical review and assessment of data quality. *Water Res.* **2019**, *155*, 410–422. [CrossRef] [PubMed]
137. Zhang, Z.; Chen, Y. Effects of microplastics on wastewater and sewage sludge treatment and their removal: A review. *Chem. Eng. J.* **2020**, *382*, 122955. [CrossRef]

138. Prata, J.C. Microplastics in wastewater: State of the knowledge on sources, fate and solutions. *Mar. Pollut. Bull.* **2018**, *129*, 262–265. [CrossRef] [PubMed]
139. Borrelle, S.B.; Ringma, J.; Law, K.L.; Monnahan, C.C.; Lebreton, L.; McGivern, A.; Murphy, E.; Jambeck, J.; Leonard, G.H.; Hilleary, M.A.; et al. Predicted growth in plastic waste exceeds efforts to mitigate plastic pollution. *Science* **2020**, *369*, 1515–1518. [CrossRef] [PubMed]
140. Krause, S.; Baranov, V.; Nel, H.A.; Drummond, J.D.; Kukkola, A.; Hoellein, T.; Smith, G.H.S.; Lewandowski, J.; Bonet, B.; Packman, A.I.; et al. Gathering at the top? Environmental controls of microplastic uptake and biomagnification in freshwater food webs. *Environ. Pollut.* **2021**, *268*, 115750. [CrossRef] [PubMed]