Identification and Quantification of Microplastics Contamination in Potato from Malang Raya, Indonesia

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Abstract. The presence of microplastics (MPs) in agricultural soil has the potential to contaminate plants and agricultural products with negative impacts on humans and living creatures. Therefore, identifying and quantifying MPs in potato farms is essential to evaluate. This study aims to estimate MPs pollutants in potato farms. This study found that potato farm components (potato seedlings, soil, organic fertilizer, potato, irrigation water and potato chips) had a total MPs content of 104 particles. The higher abundance of MPs 2.83 mL^{-1} was recorded in Pujon Kidul irrigation water and lower abundance of MPs 0.03 g^{-1} was noted in Potato chip – "OK" brand. Considering size of microplastic the maximum size of MPs 5.449 mm was calculated in Pujon Kidul irrigation water and minimum size of MPs 0.172 mm was noted in Pujon Kidul 3rd growing media. The colors of MPs identified are transparent, black, blue, red, yellow, and green. In addition, the MP's shape was 68.2 % of fibre, 26.9 % of filament, 3.8 % fragment, and 1.1 % of granules in potato farm components. The emerging pollutants must be addressed because microplastic degradation causes them to spread more widely, accumulating over tens to hundreds of years as a hidden danger.

Keywords: Emerging pollutan, harmfull, hidden danger, *Solanum tuberosum* L, toxic.

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1 Introduction

Microplastics (MPs) are very small pieces of plastic that are less than 5 mm (0.2 inch) across [1]. MPs are one of the biggest causes of waste in the world [2]. MPs pose significant effect on plants, they can enter agroecosystems and accumulate in plant bodies, causing pore space blockages on root surfaces, oxidative damage, and inhibiting nutrient and water uptake [3]. MPs also decrease germination capability and have negative effects on product quality [4]. Studies have shown that the effects of MPs on plants are widespread, affecting germination, root growth, shoot growth and biomass and length of various plant species [5]. Chlorophyll levels are commonly negatively affected, while stress indicators and stress respondents are consistently upregulated [6]. The impacts of MPs on plants can be both direct, through physical blockages and accumulation, and indirect, through effects on soil physicochemical characteristics, soil microbes, and fauna [7]. The characteristics of MPs, such as type, size, and oxygen-containing groups, as well as the additives and adsorbed environmental pollutants by the MPs, contribute to their toxicity to plants [8].

Previous studies prescribed that MPs were detected in air [9], sea salt ponds [10], organic compost [11], and commercially sold compost [12]. Moreover, the abundance of MPs in agricultural soils can vary, ranging from 4.94 items kg^{-1} to 40 800 items kg^{-1} [13]. Also, (6 433 ± 751) particles kg^{-1} MPs of green compost were discovered in the organic waste of Lithuania's Kaunas and Alytus regional waste management centres [14]. Another study found that using compost on corn fields in China for a long time polluted the soil with (3.63×10^9 to 4.99×10^9) particles $ha^{-1.}$ [15], while maize (*Zea mays* L.) is generally grown for human consumption. The MPs in soil can migrate both horizontally and vertically through the soil fauna [16]. It is important to note that the effects of MPs on soil health and crop growth can be significant, altering soil physicochemical properties and impacting soil biota and crop performance [17]. In this way, MPs in farming settings are interesting and need to be looked at carefully.

MPs in agriculture have various sources, one major source is the large-scale utilization of plastic products in agriculture which leads to the accumulation of MPs in the soil [18]. Another source is the production, consumption, and insufficient management of plastic waste, which results in the accumulation of MPs in the environment [19]. Agricultural practices such as the use of polyethylene (PETE) film, sludge recycling, long-term application of organic fertilizer, surface runoff, and sewage irrigation also contribute to the presence of MPs in soil [20]. Additionally, wastewater treatment plants are identified as a key source of MPs that may enter natural bodies of water, groundwater, or terrestrial ecosystems [21]. Overall, the sources of MPs in agriculture include plastic products used in agricultural facilities, plastic waste, agricultural practices, and wastewater treatment plants.

While the complexity of plastic pollution is being addressed, one area that has received relatively little attention is the potential contamination of agricultural ecosystems. Agriculture plays a vital role in sustaining human life, and the quality and safety of the food supply is of paramount importance. Potato (*Solanum tuberosum* L.) plants are of significance as they are a staple crop in many parts of the world. However, the impact of MPs on potato cultivation and the subsequent implications for human health remain underexplored and poorly understood. The study's goal was to find out how common MPs are in potato farms. The novelty of this study was the identification of MPs in potato farms components (potato seedling, soil, fertilizer, potato, and potato chips) which is missing in the literature. The findings of this study are significant to (i) provide new information regarding the MPs in potato farms and (ii) to assure the safety of potato farms.

2 Materials and methods

2.1 Research location

This research was categorized as exploratory research conducted in Malang Raya (Malang regency, Malang city, and Batu city), East Java, Indonesia. The choice of location was based on the consideration that East Java was the largest potato producer in Indonesia in 2021 and 2022, while Malang Regency was the third largest potato producer in East Java [22], and in the city of Malang, there was a Faculty of Agriculture that specifically researched potato cultivation and produced breeder seeds (BS) potatoes (plantlets, cuttings from plantlets, and micro tubers), G0, and G1 [23]. Likewise, because Malang Raya was a tourist area, many micro, small, and medium enterprises (MSMEs) processed potatoes into snacks, including potato chips. Data from the Office of Cooperative & MSMEs Integrated Business Service Center [*Pusat Layanan Usaha Terpadu* – PLUT, Koperasi & UMKM (*Usaha Mikro, Kecil, dan Menengah*)] in Batu City recorded approximately 19 potato chip producers - MSMEs (UMKM)] (Y.H. Saraswanto, staff of PLUT, Batu City — personal communication).

With the considerations above, the research objects are potato farmers, potato seed producers and processed potato chip products. The sample of potato farmers was determined in Pujon Kidul village (Pujon subdistrict, coordinates S7°51'20.0664" and E112°28'18.4152"), Pujon Kidul was chosen because in that village there are certified potato seed producers and distributors who are supervised by the Faculty of Agriculture, one of the universities that specifically has a potato research unit. As a comparison, potatoes were also collected at the main market "Among Tani" Batu city (coordinates S7°52'56.7048" and E112°32'0.258") which came from two villages, namely Sumber Brantas (Bumiaji subdistrict, Batu city, coordinates: S7°45'11.8188" and E112°32'11.1444"), and Ngadas (Poncokusumo subdistrict, Malang regency, coordinates: S8°2'16.4832" and E112°53'38.274"). Sumber Brantas is the village that has the largest potato land in Malang Raya, and Ngadas is a village in Malang Regency which borders Probolinggo regency, the 2nd largest potato producer in East Java [24].

Producers and distributors of potato seeds as samples in Pujon Kidul village, located at coordinates S7°51'29.2428" and E112°27'51.696", while two potato chip producers (OK brand, coordinates S7°52'21.9684" and E112°31'44.6196" and CV brand, coordinates S7°52'6.8052" and E 112°30'36.3708") were randomly selected from MSMEs potato chip producers registered at the PLUT, Batu city. As a comparison, potato chips products produced by PT PBCI, which was one of the largest snack food producers in Indonesia, have been analyzed. This "wavy" potato chip product was produced in Cikupa, Banten, West Java (coordinates; S6°13'34.7844" and E106°32'51.9576"). Samples were collected randomly in the "original taste" from three supermarkets in Malang city, namely Superindo in Bareng village (S7°58'27.6564" and E112°36'47.1816"), Superindo in Sumbersari village (S7°57'47.9088" and E112°36'49.5144"), and Superindo in Tlogomas village (S7°56'4.5348" and E112°36'16.9056").

2.2 Observed variables

The shape (fibers, filaments and fragments, and granules), color, size, and abundance of MPs (g^{-1} or mL^{-1} particles) were observed, based on Masura *et al.* [25] and Defri *et al.* [26] modification. Details of samples collected randomly were listed in Table 1.

Table 1. Objects and samples in observational research.

Number	Objects	Sample
1	Potato farmer	Production potatoes
		Soil
		Organic fertilizer
2	Seed producer	Seed potatoes G0
		Growing media 1st cyclus
		Growing media 3rd cyclus
		Irrigation water
3	Potato chip producer	Packaged potato chips

2.3 Materials

Chemicals *i.e.* hydrogen peroxide (H_2O_2), ferrous sulfate ($Fe_2SO_4.7H_2O$) and sodium chloride (NaCl) were purchased from Kimia Pratama company (Gresik city, East Java, Indonesia).

The first stage of filtration uses a stainless filter with a mesh size of 5 mm, and the second stage uses a stainless filter with a mesh size of 300 mm. To make it easier to get the MPs out after the mortar process, the first cleaning step gets rid of leaves, roots, and other bigger particles. The second cleaning is done after the sample has been spun for the identification step. After the samples have been put in a strong acid solution, they are rinsed with distilled water. Glass beakers, measure flasks, pipettes, glass bottles, vial bottles, glass stirrers, Petri plates, and mixer were also used in this study. Aluminium foil is used to cover glasses and put objects in warming ovens. Label paper was also needed to show what the sample was.

2.4 Sample preparation

The MPs analysis was carried out at the Ecological Observation and Wetlands Conservation (ECOTON) Laboratory in Gresik, East Java, Indonesia (coordinates S7°23'53.1348" and E112°31'33.5964"). In general, preparation was carried out in several stages, namely, (i) grinding the sample with a mortar and drying the materials (especially soil samples, organic fertilizer, planting media, and potatoes) in an oven (Kirin KBO-352RA, Indonesia) at a ,temperature of 80 °C (ii) filtering the samples, (iii) degradation of organic material (with H_2O_2 and Fe_2SO_4) and heating on a hot plate accompanied by a magnetic stirrer (Bante Type MS400, China) at a temperature of 70 °C for 30 min (especially for sediment samples with NaCl added), (iv) grinding again the sample with a mortar, (v) neutralization of the acid, (vi) separation of the precipitate (centrifuge corona 80-2, Indonesia), and (vii) filtration of the sample with a stainless filter, 300 mesh, accompanied by rinsing with NaCl water.

2.5 MPs identification

Pour water through a 300-mesh filter into a Petri dish to find MPs. Identification of the shape, color and size of the MPs was observed using a stereo microscope with 40x magnification (Trinocular Digital Ways Dw-tc-y Black Edition, Kaisi Rotation LED Lamp K-D056 for microscope and 51-megapixel microscope camera connected to Samsung Smart TV 32). The MPs particles found were documented, and quantitative and qualitative observations were carried out. Quantitative observations include the number of particles (fibers, filaments, fragments, and granules etc.) expressed as MPs abundance (particles g^{-1} or mL^{-1}), and particle size (mm) determined with micrometer paper placed under the petri dish, while qualitative observations, *i.e.* particle color. The abundance of MPs was calculated based on Equation (1) [Fan *et al.* [27]] modification.

$$\mathrm{N} = \frac{\mathrm{n}}{\mathrm{v}} \quad (1)$$

Where,
N : The abundance of MPs (ind. g^{-1} or mL^{-1}).
n : The number of MPs particles found.
v (L or g) : The amount of sample dry weight.

Next, the samples are stored in vials for further Fourier Transform Infrared Spectroscopy (FTIR) analysis.

3 Results and discussion

3.1 Results

As shown in Table 2, the research objects were potato farms, potato seed producers and processed potato chip products. MPs observations at potato farms are shown in Table 2, which depicts potato samples data from Pujon Kidul, Sumber Brantas and Ngadas.

Table 2. Identification and quantification of MPs contamination in potato farm.

Number	Object	Shape and number	Color and number	Size (mm)	Abundance (particle)
1	Pujon Kidul potato	Filament – 5 Fiber – 3	Blue – 4 Red – 1 Transparent – 3	0.281 to 1.106	0.05 g^{-1}
	Pujon Kidul soil	Filament – 3 Fiber – 1 Fragment – 1	Blue – 2 Black – 1 Transparent – 2	0.313 to 0.673	0.03 g^{-1}
	Pujon Kidul organic fertilizer	Filament – 3 Fiber – 3	Blue – 4 Transparent – 2	0.267 to 1.993	0.06 g^{-1}
2	Sumber Brantas potato	Filament – 2 Fiber – 1	Blue – 1 Transparent – 2	0.335 to 1.497	0.02 g^{-1}
3	Ngadas potato	Filament – 1 Fiber – 2	Red – 2 Transparent – 1	0.483 to 3.925	0.03 g^{-1}

Table 2 shows that the highest MPs pollution was detected in potatoes from Pujon Kidul (0.05 particles g^{-1}) compared to Sumber Brantas (0.02 particles g^{-1}), and Ngadas (0.03 particles g^{-1}). Looking for the cause of the high MPs, further research was carried out into G0 seeds and related materials used by certified seed breeders. Table 3 shows that growing media and irrigation water play a role in MPs contamination.

Table 3. Identification and quantification of MPs contamination in potato seed.

Number	Object	Shape and number	Color and number	Size (mm)	Abundance (particle)
1	Pujon Kidul seed G0	Filament – 4 Fiber – 5	Blue – 3 Red – 1 Green – 1 Gray – 1 Black – 1	0.461 to 2.109	0.11 g^{-1}

Continue on the next pages.

Table 3. Continue.

Number	Object	Shape and number	Color and number	Size (mm)	Abundance (particle)
			Purple – 1 Transparent – 1		
2	Pujon Kidul 1st growing media	Filament – 2 Fiber – 2 Fragment – 1	Blue – 3 Yellow – 1 Grey – 1	0.174 to 3.225	0.10 g^{-1}
3	Pujon Kidul 3rd growing media	Filament – 4 Fiber – 4 Granule – 1 Fragment – 1	Blue – 3 Red – 1 Green – 1 Transparent – 5	0.172 to 4.037	0.20 g^{-1}
4	Pujon Kidul irrigation water	Fiber – 43	Black – 18 Blue – 6 Red – 19 Green – 1	0.190 to 5.449	2.83 mL^{-1}

With the aim of increasing economic circulation, Malang Raya, as the 3rd largest potato producer in East Java [24], produced diversified potato products. One of the processed potato products was chips, which were made by MSMEs, especially as a dish for tourists. MPs contamination in potato chip samples was presented in Table 4.

Table 4. Identification and quantification of MPs contamination in potato chips.

Number	Object	Shape and number	Color and number	Size (mm)	Abundance (particle)
1	Potato chip – “OK”	Filament – 2	Blue – 2	0.280 to 0.438	0.03 g^{-1}
2	Potato chip – “CN”	Filament – 1 Fiber – 1 Fragment – 1	Red – 2 Green – 2	0.295 to 0.538	0.04 g^{-1}
3	Potato chip – “CT”	Filament – 1 Fiber – 6	Black – 5 Blue – 1 Red – 1	0.387 to 2.615	0.20 g^{-1}

3.2 Discussion

3.2.1 Potato farm and seed

3.2.1.1 Abundance

Table 2 showed that MPs contamination in potato samples in Pujon Kidul (0.05 particles g^{-1}) was higher than Sumber Brantas (0.02 particles g^{-1}) and Ngadas (0.03 particles g^{-1}). These findings supported previous research, where MPs contamination in potatoes had been reported in the Ulungur River basin in Qinghe County, Altay, Xinjiang, China [28]; Tiruchirapalli - Trichy, Tamil Nadu, India [29], Catania city, Sisilia, Italy [30], and Muğla, Southern Western of Turkey [31].

MPs were found in potatoes produced in Pujon Kidul because the land used to grow potatoes had been contaminated with MPs in the amount of 0.03 particles g^{-1}. The potato observation farm in Pujon Kidul was in the lowest area, above which there were people's houses, dairy cow farm, seed breeder screen houses, and other vegetable gardens. Runoff water from the top flows to the potato observation farm. This water flow might bring about the degradation of MPs [20].

Another suspected cause maybe the landowner's report that the observation farm often used plastic mulch. The use of production facilities, *i.e.*, plastic mulch, has been reported by several researchers to cause MPs pollution. Plastic mulch made from polyethylene (PE) caused MPs contamination of (78.0 to 1 075.6) particles kg^{-1} [32, 33] and (9.25 to 369.55) mg kg^{-1} [34]. Meanwhile, mulch made from polypropylene (PP) caused MPs pollution of (62.50 to 12 560) particles kg^{-1} [35, 33] and mulch made from polyamide (PA) as much as (320 to 12 560) particles kg^{-1} [35].

At the edge of the observation farm, there was a plastic warehouse for storing fertilizer sacks. Plastic sacks could cause MPs pollution. Likewise, the walls, roof, and floor of this warehouse used ultraviolet (UV) plastic and plastic sheeting, which could be degraded into MPs [36–40]. The observation farm was located on the side of the main road and was a shortcut for humans from lower areas to upper areas, and vice versa, which allowed careless disposal of plastic materials. All possible causes of MPs pollution above were exacerbated using organic fertilizer contaminated with MPs in the amount of 0.06 particles g^{-1} (Table 2).

The use of organic fertilizer with the "BL" brand required further policy because this organic fertilizer was produced from Probolinggo city waste. The "BL" organic fertilizer, being produced by an authorized institution, was likely used by potato (and food and vegetable) farmers in Probolinggo regency. For the record, Probolinggo regency was the area that produced the most potatoes in East Java. A number of researchers [11–15] reported that organic fertilizer was needed as a soil conditioner but can be a source of spreading MPs contaminants if the manufacturing process was careless handled. Weithmann *et al.* [41], stated that the use of compost caused MPs contamination of (11 to 895) particles kg^{-1}, while Yang *et al.* [42], stated that it was $3.50 \pm 1.71 \times 10^6$ particles ha^{-1}.

Table 3 showed the sources of MPs contamination in potatoes at Pujon Kidul Farm. The G0 seeds used by the observation farm in Pujon Kidul were contaminated with MPs of 0.11 particles g^{-1}. The analysis in Table 3 showed that the planting medium for potato stem cuttings contained MPs. The 1st growing media contained 0.10 g^{-1} particle, while the 3rd growing media contained 0.20 g^{-1} particle. These findings suggested that MPs contamination accumulated as plastic fragmentation occurred over time [43, 44, 18, 19, 37].

The cause of contaminated growing media was the use of "BL" brand organic fertilizer and contaminated irrigation water. Table 3 showed that the irrigation water used in the G0 seed breeder screen house contained 2.83 particles mL^{-1}. This irrigation water came from sources managed by the village and was distributed to every community house. These findings supported the conclusion of a 2021 study that water sources in Batu have been polluted by MPs. However, MPs contamination in water sources in Pujon Kidul was higher than Ardianto's [45] report in 11 water sources in Batu city.

3.2.1.2 MPs shape

Table 2 showed that filaments dominated over fibers, except in Ngadas potatoes, with a length of 0.281 mm to 3.915 mm. There were fragments, blue in color, with a length of 0.32 mm in the soil observed farm. Fragments were irregular plastic fragments and came from hard/strong plastic [46, 36, 37]. Plastic bottles [39], plastic feeders, plastic spoons, buckets, seedling trays, and agricultural equipment made from plastic [45] could be degraded into fragments.

A number of researchers [47–50, 36] suggested that filaments came from thin plastic, including plastic bags ("kresek" in Javanese), sachets (food packaging, toiletry packaging), fertilizer sacks, plastic mulch, polybags, and UV plastic [51, 45, 48]. Fiber came from plastic in the form of clothes washing fiber, cloth, soap and beauty equipment, cigarette filters, plastic rope, raffia, paranet, plastic sacks for harvesting, UV plastic, and glass fiber [52–54, 36, 38].

The findings in Table 2 supported previous research [50, 55], namely that it was possible for filaments to dominate because many potato farm activities used thin plastic, including fertilizer sacks, plastic mulch, polybags, and UV plastic. This was also possible due to human carelessness in throwing away plastic bags, sachets, food packaging, and similar thin plastic on land. The type of fiber found as listed in Table 2 was thought to come from wastewater from residents' houses at the top of the observed farm, including clothes washing water, wastewater from bathing, toothpaste [55, 36–38, 48, 51, 52], dairy farm, potato seeding screen house, irrigation water for seeds, organic fertilizer brand "BL"; and also the activities of vegetable farmers and agricultural inputs on the land at the top of the observed farm.

Table 3 showed different findings compared to Table 2, namely that fiber was more dominant than filament. This condition was thought to occur because the irrigation water used to water potato seed propagation contained relatively high fiber (2.83 mL^{-1}). Another possibility was the addition of fiber from the degradation of plastic water storage drums, plastic tarpaulin debris on the screen house floor, plastic used as a base for seed beads, and debris from degradation of the walls and roof of the UV screen house. The main source of fiber was in irrigation water (43 particles or 2.83 mL^{-1}) and required a more detailed study to determine efforts to minimize this contamination in future research.

3.2.1.3 Colors

Table 2 and Table 3 showed that MPs particles found in samples were predominantly colored as compared to transparent particles. A number of researchers [56–60] stated that color could be an estimate of the age of degraded plastic. The darker the color indicated the plastic was in the early stages of degradation. This phenomenon appeared in Table 2 (soil and potato) containing more transparent particles than Table 3 (seeds). Over time, the colored particles in the soil faded with the impact of increasing the number of particles. The same phenomenon could be seen in Table 3, where the 3rd growing media contained more transparent particles (5 particles) than the 1st media, while the number of particles in the 3rd growing media was twice as high as in the 1st media.

3.2.2 Potato chips

Table 4 showed MPs contamination on samples of potato chips produced by randomly selected MSMEs in Batu City, *i.e.* 0.03 g^{-1} and 0.04 g^{-1}. As a comparison, Table 4 listed potato chips made by PT PBCI, one of Indonesia's largest snack food companies also contained MPs of 0.20 g^{-1}. The raw potatoes for "wavy potato chips" were supplied from farmers at Ngantru village, Ngantang sub-district, Malang regency. Every year approximately 300 ha of farmers' land undertook partnership with seeds supplied by PT PBCI. In the following manuscript, the authors will report the identification and quantification of microplastic contamination in Ngantru village to complement this research.

The suspected microplastic contamination in potato chips comes from potato raw materials and organic fertilizer (Table 2), potato seeds and irrigation water/rainwater (Table 3), water in the process of making potato chips and cooking oil as an ingredient for frying the chips. The authors will report further on the identification and quantification of microplastic contamination in several cooking oil brands sold in the city of Malang,

These findings supported previous research that food in several countries, including China [61, 62], Ecuador [63], India [64], Indonesia [65, 66], Mexico [67], Portugal [68], Turkey [31], and United Arab Emirates [69], was contaminated with MPs. The finding of MPs contamination in potatoes and potato chips in Malang Raya should be considered by the

Food and Drug Supervisory Agency (BPOM) and the National Standardization Agency – the Republic of Indonesia (BSN) to improve food standards in Indonesia, especially in microplastic contamination parameters.

3.3 Future research

The authors planned and suggested future research, namely:

3.3.1 Fourier transform infrared spectroscopy

The data in Table 2, Table 3, and Table 4 should be enriched with Fourier Transform Infrared Spectroscopy (FTIR) analyses to identify polluting polymers, so that mitigation actions can be carried out appropriately. Samples of organic fertilizer should be added from competent producers as a comparison.

3.3.2 Bioremediation

In the agricultural sector, especially in potato cultivation it is impossible to minimize plastic material use, research on remediation, especially bioremediation, was needed. Grgić *et al.* [70] reported *Bacillus licheniformis* [(Weigmann 1898) Chester 1901] and *Lysinibacillus massiliensis* [Glazunova *et al.* 2006) Jung *et al.* 2012], and a mixed bacterial culture of *Delftia acidovorans* [(aden Dooren de Jong 1926) Wen *et al.* 1999] and *Bacillus* sp., were used for biodegradation of Low-Density Polyethylene (LDPE) and Polystyrene (PS) MPs. Auta *et al.* [50] successfully isolated nine bacteria that could degrade Polyethylene Terephthalate (PETE) and PS from 22 bacterial groups isolated from mangrove soils. After 90 d of culture, the weight loss of PETE in the experimental group was 18 %, whereas that of PS was 15 %. Lwanga *et al.* [72] isolated bacteria from earthworm guts after 60 d of treatment with MPs. Earthworm species, *i.e. Eisenia fetida* (Savigny, 1826), *Eudrilus eugeniae* (Kinberg, 1867), and *Lumbricus terrestris* (Linnaeus, 1758) were reported by a number of researchers [73–77] to be able to reduce LDPE, high-density polyethylene (HDPE), PP, polylactic acid (PLA), and polybutylene adipate terephthalate (PBAT). Ikhwan and Nurcholis [78] found that bacteria had a double potential, besides being able to degrade plastic, it also had the potential to be a biological fertilizer.

3.3.3 Growing media

Apart from the introduction of bioremediation agents, growing media used by potato seed breeders in Pujon Kidul and especially organic fertilizer must be free from MPs. Likewise, research was also planned on replacing husk charcoal with biochar. By using biochar which had greater porosity and surface area, it was hoped that MPs would be absorbed into the biochar [79, 80] so that it was not absorbed by the roots of potato seed plants.

3.3.4 Irrigation water

To minimize MPs pollution in irrigation water at seed farms in Pujon Kidul, two studies would be carried out in future research, namely i) phytoremediation [81, 82], ii) use of bio absorbents, including solid waste from coffee processor [83, 84], and biochar [79, 80].

3.3.5 Bioplastics

Gradually replacing petroleum-based plastics with bioplastics. According to researchers [85, 86], the selection policy was not just about bioplastics, but must also be biodegradable plastics, because not all bioplastics are biodegradable [87, 88]. This action takes a long time, as research on the efficiency and effectiveness of bioplastics is still being carried out. However, in the short term, seed growers should consider minimizing the use of plastic that comes into direct contact with seeds, for example in seed beds. Wooden boxes are lined with plastic sheets on the inside. Plastic should be replaced with, for example, aluminum foil.

3.3.6 In vivo *test*

In future research, *in vivo* research will be planned on the impact of potatoes contaminated with MPs on experimental animals, *Rattus norvegicus domestica* (Berkenhout, 1769), aiming should be considered by the Food and Drug Supervisory Agency (BPOM) and the National Standardization Agency - Indonesia (BSN) to improve food standards in Indonesia.

Deng et al. [89] said that microplastics between 5 and 20 µm in diameter can build up in rats' livers after 28 days of exposure to an amount of 0.5 mg d–1. When MPs gather in different organs, they can bring harmful substances from the inside to the outside through a process called concentration gradient. These substances can then spread to nearby tissues, which can cause an immune response [90]. A lot of research has shown that MPs can mess up the breakdown of bile acids, liver lipids, and amino acids [91]. MPs have been shown to cause oxidative stress, damage to cell membranes, and the stimulation of inflammatory cells and death pathways in mammalian cells. Researchers looked at rat hepatocyte cells that were 3 months old and found that microplastics caused reactive oxygen species (ROS) to be activated and DNA damage [92]. Oxidative stress seems to be going up in the liver at the same time that MPs are building up. Microplastics cause oxidative stress and changes in the metabolic balance, which lead to inflammation and worsened liver function [93].

3.3.7 Food commodity seeds

With the detection that potato seeds have been contaminated, it is planned to monitor the seeds of several food crops produced in Malang Raya as an early effort to prevent MPs contamination which has a negative impact on public health.

4 Conclusion and suggestions

This research study concluded that three potato cultivation areas in Malang Raya were contaminated with MPs. The highest contamination was found in potatoes produced in Pujon Kidul village (0.05 particles g^{-1}), followed by potatoes produced in Ngadas village (0.03 particles g^{-1}), and potatoes produced in Sumber Brantas village (0.02 particles g^{-1}). MPs contamination was high in potato from Pujon Kidul because the soil had been polluted because of the location of the observed farm at the bottom, the use of contaminated organic fertilizer (0.06 particles g^{-1}), and contaminated G0 potato seeds (0.11 particles g^{-1}).

The high level of G0 contamination was due to the planting media being contaminated with MPs, specifically the 1st media and 3rd media were 0.10 particles g^{-1} and 0.20 particles g^{-1}, respectively. Contamination of planting media was due to use, among other things, contaminated organic fertilizer (0.06 particles g^{-1}) and contaminated irrigation water (2.80 particles mL^{-1}).

Potato chip samples (production from Batu city) which were taken at random, showed MPs contamination of 0.03 particle g^{-1} and 0.04 particle g^{-1}. As a comparison, potato chips produced by a large snack factory and whose products were distributed throughout Indonesia were contaminated with MPs of 0.20 particles g^{-1}.

Based on the data above, it is recommended to take preventive measures and minimize MPs contamination by enriching this research with FTIR analysis, bioremediation research, replacing potato seed growth media, minimizing the use of conventional plastic in nurseries, conducting phytoremediation and bio absorbent research in irrigation water for potato seedlings, and *in vivo* assessment of contaminated potatoes on experimental animals, *Rattus norvegicus domestica*.

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