MICROPLASTICS IN WINES: SOURCES AND SELECTED WAYS OF CONTAMINATION

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ABSTRACT

It is currently estimated that 10% of all of the plastics produced since their invention have ended up in the ocean. Soils in agricultural and urban areas are expected to represent major environmental reservoirs of micro(nano)plastics, possibly comprehensively larger than the marine one. Microplastics as tiny plastic particles less than 5mm in size can originate from various sources, such as cosmetics, textiles, plastic packaging. The main polymers in agriculture are Polyethylene, Polypropylene, Expanded polystyrene, Ethylene-vinyl acetate copolymer, Polyvinylchloride, Polyethylene terephthalate. This article is divided into 3 main parts: microplastics (MP) in the environment, definition of MP and accumulation in food / the human body and the last part is focused on **s**elected ways of MP wine contamination description, such as pathway: soil -> grape -> drinking water -> package and wine production. Efforts to mitigate microplastic contamination include better waste management practices, promoting biodegradable and compostable packaging, and improving food processing methods.

Keywords: microplastics, viticulture, wine, environment, package

MICROPLASTICS (MP) IN THE ENVIRONMENT: WATER, SOIL AND VITICULTURE

Microplastics are present in all environments and have even been detected in humans. Worldwide studies are focusing on the contamination of food and beverages by microplastics (Chaïb et al., 2025).

Agricultural value chains used 12.5 million tonnes of plastic products in plant and animal production and 37.3 million tonnes in food packaging in 2019 (FAO, 2021).

It is currently estimated that 10% of all of the plastics produced since their invention have ended up in the ocean. Microplastics in soil are thought to be present at higher levels than in the seas and oceans (French Agency for Food, Environmental and Occupational Health and Safety, 2025).

In inland locations such as glacier and urban stormwater MP were up to two orders of magnitude greater than the concentrations in rivers that convey microplastics from inland locations to water bodies in terrestrial boundary such as estuaries. Only 20% of studies reported microplastics below 20 μm. Biodegradation can reduce the concentration and size of deposited microplastics in the terrestrial environment. Fiber percentage was higher in the sediments in the coastal areas than the sediments in inland water bodies, indicating fibers are preferentially transported to the terrestrial boundary (Koutnik et al., 2021).

The ocean represents an ultimate sink for contamination, the terrestrial environment is of critical importance for their global environmental budget and exposure of humans and biota. Soils in agricultural and urban areas are expected to represent major environmental reservoirs of micro(nano)plastics, possibly comprehensively larger than the marine one. Soils exhibit several potential exposure pathways for micro(nano)plastics to organism and human health, including contamination of groundwater aquifers (Hurley and Nizzetto, 2018). The dynamics of micro(nano)plastics fate within soil is complex.

Most agricultural plastics waste (APW) are nonrecyclable due to high soilage coefficient, different polymers in composition, physical characteristics, high cost etc. MP abundance and size were shown to decrease with soil depth. Climatic conditions and cultivations are important parameters. MP composition in mulched soils and MP prevailing forms (fibres, films, fragments), suggest additional multiple sources of MP origin in agricultural soil. Compost, treated wastewater, sewage sludge, fertilisers, textiles, wind, runoff etc. play a dominant role. MP in greenhouse soil was shown to originate from AP products used in greenhouses (e.g., twines, clips, mulching films, containers of agrochemicals, pipes, fertilisers, etc.) but also external sources (biosolids, domestic, industrial plastics etc.). MP released into the soil (e.g. through coated seeds), and MP entering soil indirectly through biosolids, compost, fertilisers, wind, runoff, play significant role (Briassoulis, 2023). Terrestrial soils are widely contaminated by MP due to the application of sewage sludge and wastewater, plastic mulching, littering, the input of tire wear from roads and atmospheric deposition. The majority of the prospected agricultural and horticultural sites were exposed to sewage sludge and mulching film application and showed concentrations of <13 000 items kg^{-1} dry soil. Microplastic concentrations in soils in the vicinity of municipal areas were 10 times larger compared to rural sites. Extreme values, such as on industrial sites, exceed the common concentrations by 2 to 4 orders of magnitude (Büks and Kaupenjohann, 2020).

The plastics most commonly found in the environment are polyethylene, polypropylene (a component of plastic food boxes) and polystyrene (often used as protective packaging) (French Agency for Food, Environmental and Occupational Health and Safety, 2025). The main polymers in agriculture by FAO (2021) are:

Polyethylene (PE) – a polymer of ethylene, that can be either: **Low density PE (LDPE)** – blown into films, or **High density PE (HDPE)** – extruded into rigid and semi-rigid products, and thick films, and protective and bale nets.

Polypropylene (PP) – a polymer of propylene often used in films and bags (woven and non-woven) and rigid crates.

Expanded polystyrene (EPS) - it is primarily used for insulation e.g. packaging for produce where temperature needs to be controlled.

Ethylene-vinyl acetate copolymer (EVA) – the copolymer of ethylene and vinyl acetate. It is an elastomeric polymer that produces materials which are "rubber-like" in softness and flexibility. The material has good clarity and gloss, low-temperature toughness, stress-crack resistance, hot-melt adhesive waterproof properties, and resistance to ultraviolet (UV) radiation.

Polyvinylchloride (PVC) – a polymer that comes in two basic forms: rigid and flexible; the rigid form of PVC is used in construction of pipe and in profile applications.

Polyethylene terephthalate (PET) – a polyester thermoplastic polymer used for fibres and containers for liquids and foods.

Viticulture with high erosion risks, plays an important role in transport and distribution of material to other terrestrial and aquatic systems. Topsoils (0–10, 10–30 cm) and plastic particles on soil surfaces from eight vineyard were sampled in the study of Klaus et al. (2024). The mean microplastic concentration was 4200 particles kg^{-1}, with detected mean sizes of 230 μm. The distribution pattern showed higher microplastic concentration in topsoil, at middle and bottom slope position. The smallest particle sizes were found in subsoil samples and bottom position. Erosion is assumed to be a potential downhill transport pathway. Management affects polymer composition. Polymer composition of micro- and macroplastics partly coincide, thus in-situ fragmentation, is considered to be the major input source (Klaus et al., 2024).

The solution could come from an integrated approach of innovative design of agricultural plastics (AP) products, including material recirculation, use of AP certified as biodegradable in soil and/or organic recycling, in combination with restriction of primary „*Micro and Nano-plastics*" presence in fertilisers, biosolids, composts etc. (Briassoulis, 2023).

DEFINITION OF MICROPLASTICS (MP)

Microplastics encompass a wide range of materials composed of different substances, with different densities, chemical compositions, shapes and sizes. There is no scientifically-agreed definition of microplastics, although they are frequently defined as plastic particles in size from 5 millimetres down to a micrometre, between 1 micrometer and 5 millimetres (French Agency for Food, Environmental and Occupational Health and Safety 2025, World Health Organization, 2019, Zajac et al., 2025). By FAO (2021) we can recognise them as: micro < 5 mm, nano < 1 μm.

All living species, from the smallest (e.g. zooplankton) to the largest (e.g. whales), can ingest them. Plastics are made not only of polymers, but also of a mixture of various additives that give the plastics their properties: flexibility, rigidity, fire resistance. Certain contaminants, whether chemical (heavy metals) or biological (bacteria), can attach themselves to the surface of plastics (French Agency for Food, Environmental and Occupational Health and Safety, 2025).

MP PRESENCE IN FOOD / HUMAN BODY

Low-cost and adaptable plastic products have crept into every part of our food systems – from fishing gear and tree guards to greenhouses (FAO, 2012). Microplastic food contamination has become a growing concern due to its potential impacts on human health. Microplastics as tiny plastic particles less than 5mm in size can originate from various sources, such as cosmetics, textiles, and plastic packaging. These particles can enter the food chain through multiple routes, such as the environment as it was already mentioned, food processing, and packaging. They can accumulate in different types of food, including seafood, drinking water, and agricultural produce. Exposure through food consumption is a significant concern, as it is difficult to avoid and can potentially cause adverse health effects. Microplastics can accumulate in the human body and have been linked to various health issues, such as inflammation, organ damage, and the disruption of endocrine and immune systems. They can act as vectors for harmful chemicals and pathogens, further exacerbating their potential health impacts. They were found to be in bottled and tap water, beer, honey (Zajac et al., 2025)

POSSIBLE WAYS OF WINE CONTAMINATION

From soil to grape

A critical concern for both producers and consumers is whether these particles can actually enter the grapevine itself. The plant absorbs water through root hairs. Evidence in crops suggests that "nanoplastics", particles even smaller than microplastics, can be absorbed by these root hairs and move into the plant's vascular system. If these particles are transported through the xylem, there is a theoretical pathway for them to accumulate in the fruit (De Schepper et al., 2013). The long life-span of grapevines (often 30 to 100 years) allows bioaccumulation that annual crops do not face. More direct route is atmospheric. During the ripening stage, grapes develop a waxy coating called the bloom. This coating is slightly sticky and acts as a magnet for atmospheric dust, which includes synthetic fibers from clothing, tires, and industrial activity. Grapes are rarely washed before crushing, airborne microplastics are moved directly into the fermentation vat.

From grape to wine

There is limited research that addresses microplastics (MP) contamination on the surfaces of fruits. Study of Nassar et al. (2025) characterizes MPs on the surface of grapes purchased from three markets. Among the produce tested from three markets (A, C, and L), grapes exhibited the highest number of MPs in market A, with 0.891 $n \cdot mm^{-2}$ as the maximum. Most MP were transparent, with every sample containing above 85% transparency, that may suggest potential origins such as the transparent packaging. MP were predominantly made of carbon and oxygen, with traces of Si, Zn, Mg, Fe, Al, and Na also detected. These elements support evidence that MPs can absorb chemical and harmful substances, which may desorb upon ingestion and pose potential risks to human health. The exposure assessment revealed that children and adults consuming grapes from market A may ingest up to $4.04 \cdot 10^{-4}$ and $9.24 \cdot 10^{-5}$ $MPs \cdot kg^{-1} \cdot day^{-1}$, respectively.

Drinking water

The potential hazards associated with microplastics come in three forms: physical particles, chemicals and microbial pathogens as part of biofilms. Although there is insufficient information to draw firm conclusions on the toxicity related to the physical hazard of plastic particles, particularly for the nano size particles, no reliable information suggests it is a concern. Limited evidence suggests that key sources of microplastic pollution in freshwater sources are terrestrial run-off and wastewater effluent. Optimized wastewater (and drinking-water) treatment can effectively remove most microplastics from the effluent. In freshwater studies, reported microplastic particle counts ranged from around 0 to 1000 $particles \cdot l^{-1}$. Regarding the microplastics in drinking-water; these studies reported particle counts in individual samples from 0 to 10 000 $particles \cdot l^{-1}$ and mean values from 10–3 to 1000 $particles \cdot l^{-1}$. A comparison of the data between freshwater and drinking-water studies should not be made because in most cases freshwater studies targeted larger particles, using filter sizes that were an order of magnitude larger than those used in drinking-water studies (World Health Organization, 2019).

Package and wine production

Use of plastics is ubiquitous in the food and beverage industries, with expanding usage in wine production. Foodstuffs can become contaminated with plastic additives through food-contact processing and packaging materials, leading to environmental and human health concerns (Plank and Trela, 2018). Beverages, often packaged in plastic, can be a source of microplastics in the human diet (Prata et al., 2020).

The origin of the microplastics found in drinks packaged in glass bottles with caps was investigated. These particles probably came from the metal caps, and more specifically from the paint that covered them. The microplastics found in the drinks were mostly the same colour and had the same composition as the paint on the caps. The paint on these caps had tiny scratches that were invisible to the naked eye and had probably been caused by friction between the caps when they were stored before use. This friction, which released particles from the surface of the caps, was thought to be the source of the microplastics found. While an average of 287 $particles \cdot l^{-1}$ were found in the water of the bottles sealed with uncleaned caps, this number decreased significantly, to 106 $particles \cdot l^{-1}$, when air was blown on the caps before they were placed on the bottles. It fell further to 87 $particles \cdot l^{-1}$ when blowing was followed by rinsing. To prevent plastic particles from being released into drinks contained in bottles sealed with caps, manufacturers could also explore other lines of action, such as changing the conditions in which the caps are stored before use, to avoid friction, or modifying the composition of the paint used on the caps (French Agency for Food, Environmental and Occupational Health and Safety).

The study of Chaïb et al. (2025) was set up to address the level of microplastic contamination in water, grape and wine. Focus was put on the impact of different containers: plastic, glass, brick, can, cubitainer, on this contamination. Heterogeneous results were obtained with mean contamination levels of 2.9 $MPs \cdot l^{-1}$ in waters, and 8.2 $MPs \cdot l^{-1}$ in wines. The most contaminated containers were glass bottles. Caps were suspected to be the main source of contamination, as the majority of particles isolated in beverages were identical to the color of caps and shared the composition of the outer paint. MPs were present in all the samples analyzed, with contamination levels heterogeneous depending on beverages, with a size between 30 and 500 µm. A cleaning step before encapsulation can significantly reduce beverages' contaminations. However, cleaning does not remove all the MPs from the capsule. The wine found in bricks showed the highest MPs content (30.0 $MPs \cdot l^{-1}$). The level of MPs was significantly different between brick and large plastic bottles, between brick and glass and between small plastic and large plastic, and between brick and cubitainer. A significant difference in contamination levels was also observed among the different types of wine.

Method for detection of microplastics in white wines capped with synthetic stoppers was explored. Quantification in the optical microscope identified up to 5,857 $particles \cdot l^{-1}$ (Prata et al., 2020).

CONCLUSION

Efforts to mitigate microplastic contamination include better waste management practices, promoting biodegradable and compostable packaging, and improving food processing methods. Microplastic contamination of food is a complex issue requiring a multidisciplinary approach to address its ecological and human health implications.

The solution could come from an integrated approach of innovative design of agricultural plastics products, including material recirculation, use of AP certified as biodegradable in soil and/or organic recycling, in combination with restriction of primary „*Micro and Nano-plastics*" presence in fertilisers, biosolids, composts etc.

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