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The Role of Amniotic Fluid as a Biomarker for Identifying and Evaluating Microplastic Exposure

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Keywords

Microplastics; Amniotic fluid; Pregnant women; Biomarker; Fiber

Abstract

Microplastics (MPs) are environmental contamination that can potentially threaten the health of pregnant women and fetuses. This study aims to identify the presence and characteristics of Microplastics (MPs) in amniotic fluid and evaluate their potential as biomarkers of exposure during pregnancy. The study used a cross-sectional observational approach with 14 amniotic fluid samples collected aseptically in Gresik Regency. Analysis was performed through biological digestion using KOH and identification of particles in the samples by microscopy. Results showed all samples contained MPs dominated by Fiber type. This finding confirms the ability of MPs to penetrate biological barriers and reach an environment that should be sterile for the fetus. This study confirms the importance of monitoring MPs exposure during pregnancy and recommends utilizing amniotic fluid as a biomarker to support prevention and mitigation strategies for maternal and fetal health risks.

INTRODUCTION

Microplastic (MP) contamination has become a global environmental issue with the potential to cause serious impacts on human health. MPs are defined as plastic particles measuring less than 5 mm in size, which are now widely found in the environment and have been proven to contaminate human biological systems (Sutkar et al., 2023). According to Ragusa et al. (2021), plastic is an extremely abundant material, with total global production reaching 400 million tons per year. Plastics can degrade into micro-plastics and nanoplastics due to exposure to heat, ultraviolet radiation, and mechanical friction. MPs can enter the human body through various pathways, including air, water, and food consumption. Due to their very small size and their ability to bind pollutants, MPs can penetrate different parts of the body, including the bodies of pregnant women (Tian et al., 2025).

Various international studies have confirmed the presence of MPs in critical components during pregnancy, such as the placenta and amniotic fluid. These findings indicate that MPs are capable of crossing essential biological barriers that function to protect the fetus (Barrozo et al., 2024; Halfar et al., 2023; Ragusa et al., 2021; Weingrill et al., 2024). A study conducted by Zhang et al. (2025) identified PVC, PP, and PBS microplastics in more than 88% of placental samples from a large population of 1,121 pregnant women. Other studies have also documented the presence of various MP polymers in amniotic fluid and placental tissue, confirming that microplastics are not only present but also accumulate in significant amounts. They are capable of crossing the placental biological barrier, penetrating tissues and cellular barriers, and ultimately influencing various obstetric outcomes (Barrozo et al., 2024; Zhu et al., 2023).

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MP exposure during pregnancy may disrupt fetal development and placental function, as MPs can carry toxic chemical additives and trigger oxidative stress responses that damage cells (Sun et al., 2024; Tian et al., 2025). This suggests that the human biological defense system is not always capable of fully filtering or eliminating MPs, allowing them to persist in the body and potentially cause long-term effects (Massardo et al., 2024).

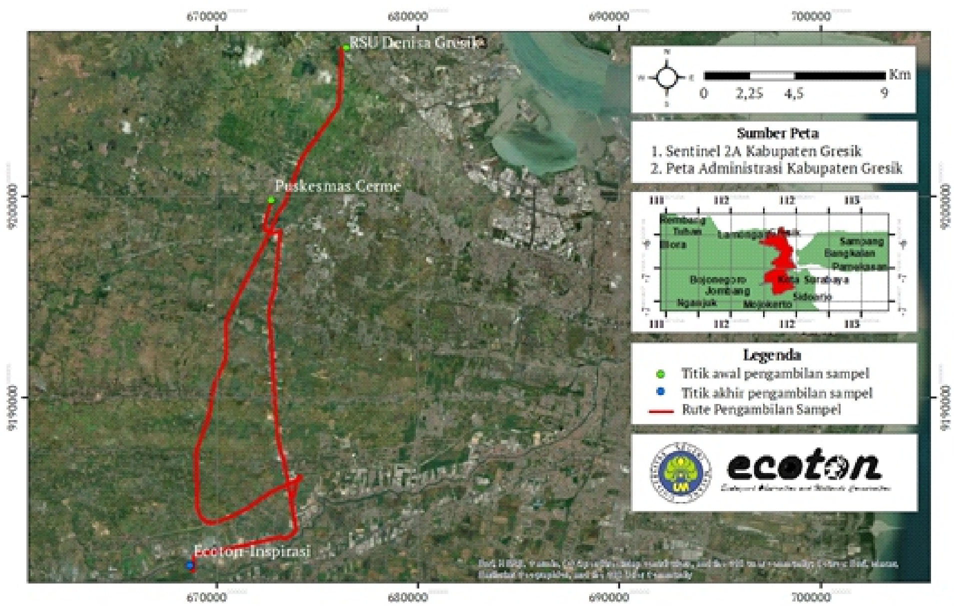
In Indonesia, research on the presence of MPs in various environmental media has begun to develop; however, studies specifically examining MPs in the amniotic fluid of pregnant women remain very limited. This creates a knowledge gap that needs to be urgently addressed, considering the potential impacts of MPs on maternal and fetal health. Gresik Regency was selected as the research location due to its high daily plastic consumption and significant plastic pollution burden, largely originating from industrial activities and continuously increasing population density. Data from the Environmental Agency (DLH) of Gresik Regency indicate an increasing trend in plastic waste generated from both households and industries each year (Dwijayanti & Arif, 2023; Sholihah et al., 2025). As a result of these conditions, Gresik is considered a high-risk area for MP exposure, including among pregnant women. Therefore, this study is highly important as an initial step to identify microplastic exposure among pregnant women in Gresik and to provide a scientific basis for the development of prevention strategies and mitigation measures to address its potential impacts.

This study aims to analyze the presence and characteristics of MPs in amniotic fluid, as well as to examine and evaluate the potential of amniotic fluid as a biomarker that can be used to assess the level of MP exposure during pregnancy and its impact on the fetus.

RESEARCH METHODS

This study employed an observational-analytic approach with a cross-sectional design to analyze the presence and characteristics of MPs in amniotic fluid as an indicator of exposure during pregnancy. The data collected were primary data in the form of biological amniotic fluid samples, with the main indicators including the number of particles and the types of MPs identified in each sample.

The study was conducted in Gresik Regency, East Java, from June to July 2025. The area was selected because it is a coastal



Source: Processed Primary Data, (2025)

Figure 1

Location of Amniotic Fluid Sample Collection

region with intensive industrial activities and high daily plastic consumption, making it highly vulnerable to MP exposure, including among vulnerable groups such as pregnant women. Samples were obtained from two healthcare facilities, namely Cerme Community Health Center and Denisa Hospital, which were considered representative of the characteristics of the pregnant population in the area.

A total of 15 amniotic fluid samples were collected aseptically from the amniotic sacs of postpartum mothers, with inclusion criteria including full-term singleton pregnancies (≥37 weeks) and no history of comorbidities. The samples were stored in glass or stainless-steel containers to prevent external contamination and then preserved at −80°C until the time of analysis.

The analysis process was conducted at the ECOTON Laboratory using a 10% potassium hydroxide (KOH) solution, with 30 mL applied to each sample to dissolve the biological tissues contained in the samples. This was followed by incubation at a temperature below 70°C for 30 minutes to separate MP particles from the remaining organic material, allowing them to be identified under a microscope. Data were analyzed using a quantitative descriptive approach by observing and identifying MP particles in each sample using digital and binocular microscopes. Detected particles were then counted and classified based on their type and observed size. The observational results were systematically recorded for each sample, and percentages were calculated to describe the distribution of both the number and types of MPs. Finally, the data were presented in tables and figures to facilitate the interpretation of MP contamination patterns in amniotic fluid.

RESULTS AND DISCUSSION

This study was conducted to identify the presence of MPs in amniotic fluid obtained from postpartum mothers at two healthcare facilities. The analysis showed that all amniotic fluid samples studied contained MP particles, with a contamination rate reaching 100%, with none free of microplastic particles. This finding indicates that MPs are able to penetrate the internal biological environment during pregnancy, particularly the amniotic fluid, which acts as a protective barrier for the fetus. Two types of MPs were identified in the samples: fibers and films. The distribution of the number and types of MPs found is shown in Table 1.

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Based on the recapitulation in Table 1 above, fiber was the most dominant type of microplastic, with a total of 155 particles, equivalent to 98.1% of the total detected particles, while the film type was found in only 3 particles, accounting for 1.9%. Visually, fibers appear as thin, elongated strands, whereas films appear as

Table 1
Distribution of Microplastic Count

Types of Microplastics	JNumber of Particles	Percenta ge (%)
Fiber	155	98,1%
Film	3	1,9%

Source: Processed Primary Data, 2025

Source: Primary Data Processed, (2025)

Figure 2

Microplastic Findings in Amniotic Fluid

thin, irregular transparent sheets. Fiber is one of the MP types that is most easily transported and retained within biological tissues due to its elongated and flexible structure. This enables it to cross biological barriers, accumulate within the circulatory system, and raise serious concerns regarding its potential health impacts especially when detected in vital fluids such as blood or amniotic fluid, which are supposed to remain sterile (Guardian, 2025).

Upon further analysis, the total number of MPs identified across all samples reached 158 particles. From this total, an average of approximately 11.29 MP particles per sample was obtained. In terms of volume concentration, each 1 milliliter (mL) of amniotic fluid contained approximately 0.38 MP particles.

The findings of this study are supported by various previous studies that have reported the presence of MP particles in amniotic fluid. Several international studies have shown that MPs are not only detected in blood, placenta, or other body tissues, but have also been successfully identified in the amniotic fluid of pregnant women. A previous study by Halfar et al. (2023) analyzed 20 amniotic fluid samples and placental tissues from 10 patients using FTIR-ATR spectroscopy following alkaline digestion with KOH. The study detected MPs and polymer additives in 9 out of 10 patients, with a total of 44 identified particles, predominantly chlorinated polyethylene (CPE) and calcium-zinc PVC stabilizers measuring 10–50 μm.

In addition, a study conducted by Xue et al. (2024) provided stronger evidence by analyzing 40 amniotic fluid samples from pregnant women using Laser Direct Infrared Spectroscopy (LD-IR). The results showed that MPs were detected in 32 out of 40 samples (80%), with an average abundance of 2.01 ± 4.19 particles per gram. The most dominant polymers were polyethylene (PE) at 38.8% and chlorinated polyethylene (CPE) at 26.98%. Furthermore, most particles ranged in size from 20–100 μm, and the most common shape identified was fragments (71.23%). The study also found a significant negative correlation between the number of MPs in amniotic fluid and gestational age, indicating that higher MP levels were associated with lower gestational age. Additionally, the study demonstrated that seafood consumption and bottled water intake were significantly positively correlated with higher MP levels in amniotic fluid.

MPs can enter the human body through three main pathways: ingestion, inhalation, and dermal contact. The ingestion pathway primarily originates from contaminated seafood and bottled drinking water, which has been reported to contain MPs in approximately ≥92% to

93% of samples (Li et al., 2023). Exposure through inhalation occurs when MP particles present in the air, household dust, or textile fibers are inhaled, whereas dermal exposure may result from contact with synthetic clothing, non-stick cookware, and other plastic surfaces (Ramsperger et al., 2023).

Once inside the body, particularly particles measuring 20–100 µm, MPs cannot be digested and may circulate in the bloodstream, allowing bio-accumulation to occur in various organs, including the placenta (Luo et al., 2025). Due to their very small size, MPs are capable of crossing the placental barrier through placental transfer mechanisms and entering the fetal system. This mechanism creates an opportunity for foreign substances, including plastic additives, to pass through the biological barriers between the mother and the fetus (Tian et al., 2025).

After crossing the placenta, MPs can reach the amniotic fluid, an environment that should be sterile for the fetus. Physiologically, by the 8th week of pregnancy, amniotic fluid begins to contain fetal urine, and by the 28th week, fetal urine becomes its primary component (Underwood et al., 2005). This condition indicates that if the amniotic fluid has been contaminated with MPs, the fetus may be exposed even before birth (Wetzel, 2025; Zimmermann, 2024). Therefore, the detection of MPs in amniotic fluid in this study strengthens its role as a potential biomarker for identifying exposure during pregnancy, while also providing a scientific basis for prevention efforts and risk mitigation strategies for maternal and fetal health. These findings demonstrate that MP particles are capable of crossing the placental barrier and entering the amniotic environment, which should serve as a sterile and protected space for the fetus.

The consistency of these findings strengthens the evidence that MP exposure during pregnancy is capable of crossing the placental barrier and reaching the amniotic fluid, which should function as a sterile and protective environment for the fetus. Particles measuring <10 micrometers, particularly polyethylene and polystyrene, have the potential to disrupt placental function through oxidative stress, inflammation, and interference with oxygen and nutrient exchange, which may trigger intrauterine growth restriction (IUGR). This condition can affect fetal growth and increase the risk of neurological, immunological, metabolic disorders, as well as degenerative diseases later in life. Moreover, MPs can carry harmful additives and other toxic pollutants that may amplify their biological effects on both the mother and the fetus. These findings emphasize that the biological systems of pregnant women, including the amniotic fluid, are no longer fully protected from plastic contamination. Therefore, MP exposure should be considered an important risk factor in reproductive health and fetal development (Amereh et al., 2022).

CONCLUSION

This study demonstrates that MPs are capable of penetrating the biological barriers of pregnant women and can be detected in amniotic fluid, which should serve as a protected environment for the fetus. These findings confirm that MP exposure during pregnancy is a real phenomenon that must be taken seriously, as it has the potential to impact maternal health and fetal development. Furthermore, this study indicates that amniotic fluid has significant potential as a biomarker for evaluating the level of MP exposure during pregnancy. These results provide an important foundation for preventive efforts, maternal and fetal health monitoring, and the development of future risk mitigation strategies related to MP exposure.

REFERENCES

Amereh, F., Amjadi, N., Bandpei, A. M., Isazadeh, S., Mehrabi, Y., Eslami, A., Naeiji, Z., & Rafiee, M. (2022). Placental Plastics in Young Women from General Population Correlate with Reduced Foetal Growth in IUGR Pregnancies. *Environmental Pollution*, *314*(120174). https://doi.org/10.1016/j.envpol.2022.120174

Barrozo, E. R., Garcia, M. A., Jr, M. D. J., Hayek, E. El, Castillo, E. F., Gonzalez-Estrella, J., Shope, C., Suter, M., Campen, M. J., & Aagaard, K. M. (2024). 33 Bioaccumulation of Microplastics in Placentae Associated with Environmental Chemical Exposures and Obstetrical Outcomes. *American Journal of Obstetrics & Gynecology*, *230*(S27). https://doi.org/10.1016/j.ajog.2023.11.051

Dwijayanti, K., & Arif, L. (2023). Implementasi Pengelolaan Sampah pada Pemrosesan Akhir. *Jurnal Kebijakan Publik*, *14*(4), 491–498.

Guardian, T. (2025). *The Life of Microplastic: How Fragments Move Through Plants, Insects, Animals – and you*. The Guardian.Org.

Halfar, J., Cabanova, K., Vavra, K., Delongova, P., Motyka, O., Spacek, R., Kukutschova, A., Simetka, O., & Heviankova, S. (2023). Microplastics and Additives in Patients with Preterm Birth: The First Evidence of their Presence in Both Human Amniotic Fluid and Placenta. *Chemosphere*, *343*(140301). https://doi.org/https://doi.org/10.1016/j.chemosphere.2023.140301

Li, H., Zhu, L., Ma, M., Wu, H., An, L., & Yang, Z. (2023). Occurrence of Microplastics in Commercially Sold Bottled Water. *Science of the Total Environment*, *867*(161553). https://doi.org/https://doi.org/10.1016/j.scitotenv.2023.161553

Luo, Q., Tan, H., Ye, M., Jho, E. H., Wang, P., Iqbal, B., Zhao, X., Shi, H., Lu, H., & Li, G. (2025). Microplastics as an Emerging Threat to Human Health: An Overview of Potential Health Impacts. *Journal of Environmental Management*, *387*(125915). https://doi.org/https://doi.org/10.1016/j.jenvman.2025.125915

Massardo, S., Verzola, D., Alberti, S., Caboni, C., Santostefano, M., Verrina, E. E., Angeletti, A., Lugani, F., Ghiggeri, G. M., Bruschi, M., Candiano, G., Rumeo, N., Gentile, M., Cravedi, P., Maestra, S. La, Zaza, G., Stallone, G., Esposito, P., Viazzi, F., … Artini, C. (2024). MicroRaman Spectroscopy Detects the Presence of Microplastics in Human Urine and Kidney Tissue. *Environmental International*, *184*(108444). https://doi.org/https://doi.org/10.1016/j.envint.2024.108444

Ragusa, A., Svelato, A., Santacroce, C., Catalano, P., Notarstefano, V., Carnevali, O., Papa, F., Rongioletti, M. C. A., Baiocco, F., Draghi, S., D'Amore, E., Rinaldo, D., Matta, M., & Giorgini, E. (2021). Plasticenta: First Evidence of Microplastics in Human Placenta. *Environment International*, *146*, 1–8. https://doi.org/10.1016/j.envint.2020.106274

Ramsperger, A. F. R. M., Bergamaschi, E., Panizzolo, M., Fenoglio, I., Barbero, F., Peters, R., Undas, A., Purker, S., Giese, B., Lalyer, C. R., Tamargo, A., Moreno-Arribas, M. V., Grossart, H.-P., Kühnel, D., Dietrich, J., Paulsen, F., Afanou, A. K., Zienolddiny-Narui, S., Hammer, S. E., & Ervik, Torunn Kringlen Laforsch, C. (2023). Nano- and Microplastics: A Comprehensive Review On their Exposure Routes, Translocation, and Fate in Humans. *Nano Impact*, *29*(100441). https://doi.org/https://doi.org/10.1016/j.impact.2022.100441

Sholihah, A. A., Ariestawati, A. S., & Nawangsari, E. R. (2025). Pemberdayaan Masyarakat Melalui Bank Sampah Induk Petiken Lestari di Kecamatan Driyorejo Kabupaten Gresik. *Indonesian Research Journal on Education*, *5*(4), 1042–1049.

Sun, H., Su, X., Mao, J., Liu, Y., Li, G., & Du, Q. (2024). Microplastics in Maternal Blood, Fetal Appendages, and Umbilical Vein Blood. *Ecotoxicology and Environmental Safety*, *287*(117300).

https://doi.org/https://doi.org/10.1016/j.ecoenv.2024.117300

Sutkar, P. R., Gadewar, R. D., & Dhulap, V. P. (2023). Recent Trends in Degradation of Microplastics in the Environment: A State-of-the-Art Review. *Journal of Hazardous Materials Advances*, *11*(100343). https://doi.org/https://doi.org/10.1016/j.hazadv.2023.100343

Tian, J., Liang, L., Li, Q., Li, N., Zhu, X., & Zhang, L. (2025). Association Between Microplastics in Human Amniotic Fluid and Pregnancy Outcomes: Detection and Characterization Using Raman Spectroscopy and Pyrolysis GC/MS. *Journal of Hazardous Materials*, *482*(136637).https://doi.org/10.1016/j.jhazmat.2024.136637

Underwood, M. A., Gilbert, W. M., & Sherman, M. P. (2005). Amniotic Fluid: Not Just Fetal Urine Anymore. *Journal of Perinatology*, *25*(5), 341–348. https://doi.org/10.1038/sj.jp.7211290

Weingrill, R. B., Garcia, J., Lee, M.-J., & Urschitz, J. (2024). Investigating the Effects of Microplastic Accumulation on Women's Health During Pregnancy. *Placenta*, *153*(e7). https://doi.org/10.1016/j.placenta.2024.05.020

Wetzel, W. (2025). *Detecting Microplastics in Human Amniotic Fluid*. Spectroscopy Solutions For Materials Analysis.

Xue, J., Xu, Z., Hu, X., Lu, Y., Zhao, Y., & Zhang, H. (2024). Microplastics in Maternal Amniotic Fluid and Their Associations with Gestational Age. *The Science of the Total Environment*, *10*(920), 171044. https://pubmed.ncbi.nlm.nih.gov/38382607/

Zhang, S., Chen, H., Li, L., Li, Z., & Wang, D. (2025). Exposure to Placental Microplastic and Placental and Umbilical Cord Blood Telomere Length. *Ecotoxicology and Environmental Safety*, *302*(118536). https://doi.org/10.1016/j.ecoenv.2025.118536

Zhu, L., Zhu, J., Zuo, R., Xu, Q., Qian, Y., & AN, L. (2023). Identification of Microplastics in Human Placenta Using Laser Direct Infrared Spectroscopy. *Science Of The Total Environment*, *856*(159060). https://doi.org/https://doi.org/10.1016/j.scitotenv.2022.159060

Zimmermann, L. (2024). *Microplastics Found Along the Maternal-Fetal Axis, Impacting Placenta*. Aurora Project