# Identification and Removal of Microplastics in Well Water Around the Landfill Piyungan Yogyakarta with Activated Carbon

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**Abstract**

The city of Yogyakarta produces an average of 270 tons of waste every day, which causes a buildup of waste at the communal waste landfill Piyungan. This causes microplastics to be absorbed into the soil and infiltrate water in the area around the landfill. Seeing this problem, researchers provided a solution to reduce microplastics in well water using the adsorption method, using activated carbon adsorbents. This research aims to identify microplastics in the water in dug wells around the landfill and reduce the microplastic content. The research used an adsorption method using activated carbon and carried out FTIR analysis tests to analyze the composition of polymers contained in microplastics in dug wells. The variables used in the research were the amount of activated carbon adsorbent and the length of contact time. The results obtained were in the form of microplastics in several forms such as fragments, filaments, fibers and films. The results of microplastic adsorption showed that the number of microplastics before adsorption was 17470 particles/L and after adsorption with a weight variation of 6% and a time of 60 minutes. Meanwhile, in FTIR analysis, the wavelength of the sample before adsorption with activated carbon was obtained with a peak wave point of 3325.5 cm.$^{-1}$, 2128,3 cm$^{-1}$, and 1636.3 cm$^{-1}$ and wavelength after adsorption with activated carbon with a peak point of 3340.6 cm$^{-1}$, 2107,8 cm$^{-1}$, and 1637,2 cm$^{-1}$ so it is estimated that the sample contains Polystyrene (PS), Polyethylene (PE), and Polyvinyl Chloride (PVC).



**Keywords:** adsorption, activated carbon, microplastics, well water, waste landfill

## INTRODUCTION

Microplastics are small particles originating from plastic with a size of less than 5 mm (Lusher et al. 2017). According to Wijaya and Trihadiningrum (2020), water flow and UV radiation cause plastic polymers to degrade to form smaller parts, while biological methods make it difficult to break down plastic polymers. Microplastic identification in Yogyakarta has been found, one of which is in well water near the Piyungan waste landfill (Utami & Liani 2021).

In 2011 the Piyungan landfill was able to accommodate 600 tons of waste produced every day and has been operating for 25 years, there is 10% plastic waste at the landfill. It will peak beyond capacity in 2012 and is projected to increase until now (Munandar and Mulasari 2019). Residents around the landfill use well water as a daily necessity, so water contaminated by microplastics can contaminate infiltration water and cause health problems for living creatures that consume the water.

Based on previous research, microplastic content was found to originate from leachate around the landfill (Utami & Agustina, 2022). The abundance of types of microplastics in the form of fibers, films, fragments, and granules. The abundance of microplastics identified was 154.80 ± 21.22

particles/L. This shows the high level of plastic waste pollution in the environment around the landfill. In another work using the ozonation and granular activated carbon filtration system, the effectiveness of reducing microplastics was 82.1% to 86% (Wang 2020). Furthermore to compare the reduction of microplastic levels with activated carbon in raw water and water after processing obtained separation results of about 81% to 83% (Pivokonsky et al., 2018). The ability of activated carbon to absorb microplastic levels at concentrations of 0.2 g/l; 0.4 g/L; 0.6 g/ l; 0.8; and 1.0 g/ L achieved separation efficiency of 95,5%; 88,5%; 82.8%; 78.0%; and 59.2% (Napi et al., 2023).

Previous studies have been carried out to reduce the microplastic content in wastewater. Kim and Park (2021) have investigated the use of electrocoagulation and granulated activated carbon to reduce microplastics in wastewater. steps. This study demonstrates that activated carbon with thermal regeneration is a tertiary process that can efficiently prohibit the release of microplastics and circulation of microplastics in the natural environment. Napi and co-workers (2023) reported that activated carbon granulates in a column system could reduce microplastics in model water by 95%. MP particles are immobilized by the activated carbon predominantly by filtration process by being entangled with small particles/chips or stuck between the activated carbon particles. Microplastics are insignificantly removed by adsorption process through entrapment in carbon porous structure or attachment onto the surface. Although the efficiency of activated carbon for removing microplastics in water is quite high, the method used in previous research was quite complicated. We therefore report in this paper the identification and removal of microplastics in well water by relatively simple batch adsorption and filtration methods.

## METHODS

### Materials

In this research, saturated NaCl solution, $H_2O_2$ 30%, water from dug wells around the Piyungan landfill, distilled water, and 200 mesh granular activated carbon prepared from coconut shells were used.

### Procedures

Water samples were taken from several wells in the area around the landfill Piyungan Yogyakarta. Samples were obtained by drawing water and then storing it in dark-colored jerry cans.

Removal of microplastics has been carried out by mixing granulate activated carbon with water samples. The ratio of activated carbon adsorbent was 2%; 4%; and 6% (w/v). The solution was stirred for a contact time of 20; 40; 60 minutes. Solid activated carbon was separated from the water samples by filtering using filter paper. The abundance of microplastics in the water samples before and after treatment by activated carbon has been carried out using microscopic experiments.

To identify the existence of microplastics in water samples the separation of microplastic particles is carried out using the method of Wet Peroxide Oxidation (WPO). Water samples were added to hydrogen peroxide 30% and followed by heating at a hot plate magnetic stirrer for 30 minutes. A saturated NaCl solution was added to separate organic compounds in water samples. The precipitate was separated using distilled water and filtered with filter paper. The form types of microplastics were identified by optical microscope with 2000 x magnification. FTIR analysis was performed to identify specific functional groups of microplastic components.

## RESULT AND DISCUSSION

### Types of microplastics

The identified form types of microplastics in well water located around Piyungan landfill are presented in Figure 1. These micrographs were captured by an optic microscope with 2000x magnification. The forms of microplastics are filaments, fibers, films, and fragments.

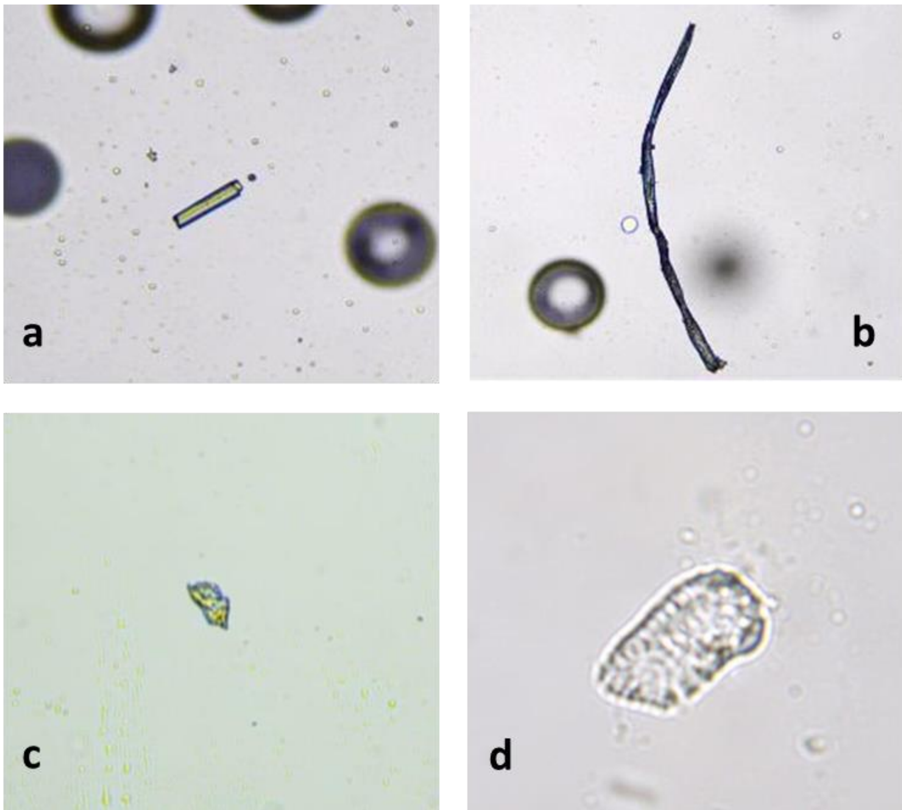


**Figure 1.** Form types of microplastics: (a) filament, (b) fiber, (c) fragment (d) film

Fragments are microplastic particles that are larger and have more regular edge shapes. Not only that, the fragments also have porous and rough texture areas (Ding et al. 2019). Microplastic fragments can bind organic materials and metal ions (Guo et al. 2018).

Fiber is a microplastic with a long and flat area (Ding et al. 2019). Alam *et al.*, (2019) reported that densely populated settlements that still use river flows as a means for sanitation purposes, for washing, bathing, and defecating, could be the cause of an increase in the number of microplastics in the form of fibers. Fish traps, surface runoff, and atmospheric deposition can also be potential sources for the formation of fiber-type of microplastics (Browne et al., 2015). Microplastics in the form of filaments and fibers generally come from equipment used by anglers and fishermen, such as nets or fishing lines, rope waste, and strands of thread (Nor and Obbard, 2014).

Microplastics in the form of films come from plastic parts that have sheets that are easily brittle and very thin. Film types of microplastics do not have a fixed shape at the edges and have many wrinkles. Microplastics in film form are obtained from fragments of food packaging or plastic bags with low density. This type of microplastic is easily carried by water flows because it is light and has a low-density (Azizah et al, 2020).

In addition to identifying the shape of microplastic particles, functional group analysis has also been carried out using FTIR to determine the type of microplastic present. The results of FTIR analysis of microplastics show characteristic spectra as presented in Figure 2. Identification of the polymer types of microplastics by FTIR was performed in a wavelength range of 2.5 to 25 $\mu$m or wave number range of 400 to 4000 $cm^{-1}$. The IR spectra peaks obtained are compared to several functional groups that may exist in microplastics as presented in Table 1 (Mikulec *et al.*, 2023).

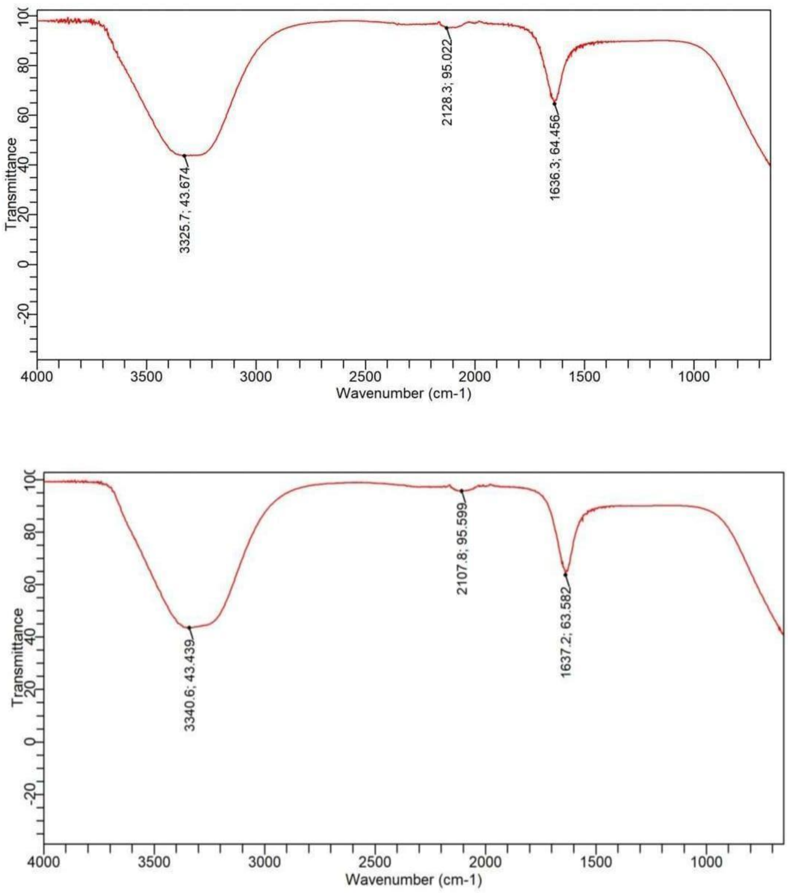


**Figure 2.** FTIR characteristic spectrum of microplastic samples before (upper) and after (lower) treatment with activated carbon

Figure 2 shows the IR spectra of microplastic samples before and after treatment with activated carbon, both samples have spectra with slight differences in peak values. The existence of these IR spectra peaks follows the analysis results reported by Utami and Liani, (2021). They reported similar IR spectra with a series of the wave number of 3405.77 $cm^{-1}$, 2069.93 $cm^{-1}$, 1635.91 $cm^{-1}$; and 583.5 $cm^{-1}$. These IR absorption band peaks indicate the presence of several typical functional groups, which can be used to identify the type of plastic polymer. These data show the possibility of approaching polymeric microplastics polyethylene (PE), polyvinyl chloride (PVC), and polystyrene (PS) in both samples. The peak of 3340.6 $cm^{-1}$ indicates the presence of hydrogen bonds as a constituent of polystyrene. According to Sumarni et al., (2013), polystyrene has a peak of wave number of hydrogen bonds at 3200 $cm^{-1}$ - 3600 $cm^{-1}$, the C=C bond at around 2700 $cm^{-1}$ - 3000 $cm^{-1}$, while the C-C bond at around 1500 $cm^{-1}$ - 1675 $cm^{-1}$. C-H bonds are thought to be the main structure of polymer compounds polyethylene (PE) and is at the wave number peak of 2915 $cm^{-1}$ up to 2935 $cm^{-1}$ (Syakti et al., 2017), while hydroxyl bonds are also constituents of polyethylene (PE) with a wave number of 3050 $cm^{-1}$ up to 3700 $cm^{-1}$ (Paço et al., 2017). Polyvinyl chloride (PVC) is characterized by OH bonds with a wave number of 2446.79 $cm^{-1}$ up to 3421.72 $cm^{-1}$, while the C=O bond is at a wave number of 1722.43 $cm^{-1}$, 1627,92 $cm^{-1}$, and 2860,43 $cm^{-1}$, up to 2962.66 $cm^{-1}$. This result is in line with the result reported by Liu et al., (2021) that the C=C bond is characterized at around 1636 $cm^{-1}$ and hydrogen bonds at a range of 1800 - 1500 $cm^{-1}$. Wang et al., (2018) identified the existence of PVC that is specified by H-bonds on wave number of 1800 - 1300 $cm^{-1}$ and the approximate stretching vibration of the

C-Cl bond on wave number of 700 - 550 $cm^{-1}$. According to Shahul Hamid et al. (2018), parts of the Asian continent contain polypropylene and polyethylene microplastics.

**Table 1**. Functional groups of PE, LDPE, HDPE, PP, and PS in microplastics

| Functional Group | Wavenumber ($cm^{-1}$) for Floating Polymers | | | | |
|---|---|---|---|---|---|
| | PE | LDPE | HDPE | PP | PS |
| $-CH_2$ rocking | 710/717 | 719 | | 840 | |
| $-CH_3$ groups deformation | | 1377 | | | |
| $-CH_2$ scissoring | 1462/1460 | | 720 | | |
| C–C stretch | | | 1080 | 973 | |
| –C=C– stretch | | 1462 & 1472 | | | 1492.7 &1452.2 |
| $CH_2$ bending | | | 1470 | | |
| C=O stretching | -/1745 | | | | |
| Symmetric–$CH_2$ stretching | 2847/2840 | 2847 | 2850 | | |
| Asymmetric–$CH_2$ stretching | 2915/2910 | 2915 | | 2920 | |
| $-CH_3$ stretching | | | 2965 | 2950 | 2921.9–2848.6 |
| O–H stretching | -/3600 | ≈3600 | | | 3446.5 |

(source: Mikulec et al., 2023)

**Reducing of microplastics**

In this study, the effect of activated carbon adsorbent on the microplastic abundance was investigated under the variable of adsorbent percentage and contact time. The abundance of microplastics has been calculated using the formula: of Masura *et al*. (2015).

$$\text{Abundance of microplastics} = \frac{\text{Number of microplastic particles (Particles)}}{\text{Filtered water volume (L)}} \quad (1)$$

The effect of the amount of activated carbon adsorbent on the abundance of microplastics is shown in Figure 3 and Figure 4 respectively. In both figures, it is shown that in the range of 2 - 6% the greater the percentage of active carbon, the smaller the abundance of microplastics. This shows a significant reduction in microplastic content in water samples. The reduction in microplastic content in water samples can reach 50% of the initial content. Microplastic particles of various types enter and are trapped in the pores of activated carbon or bound to its surface. As is generally known, activated carbon is a porous material with varying pore sizes. Besides that, activated carbon also has a relatively large specific surface area (Napi et al, 2023). The presence of pores and surface area of this material allows it to absorb various particles, including microplastics.

The reduction of microplastic particles in water with activated carbon is greater as the contact time increases (Figure 5). Microplastic adsorption experiments with a 6% percentage of granulated activated carbon and stirring for 20 minutes showed a reduction in microplastic content of around 42%, for 40 minutes 57%, and 60 minutes 82%. Kinetically, the adsorption of microplastic particles on activated carbon depends on the contact time. So far no further studies have been carried out into the optimum contact time.

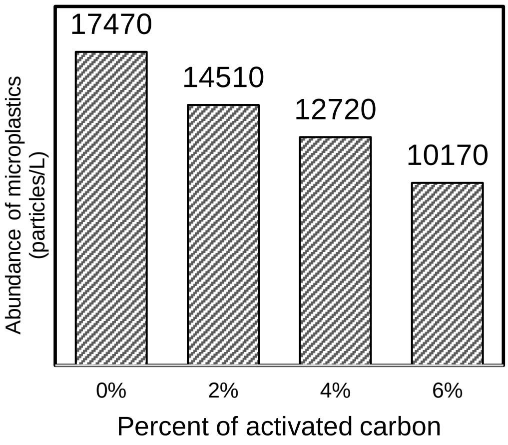


**Figure 3**. The effect of activated carbon percentage on the abundance of microplastics for a contact time of 20 minutes

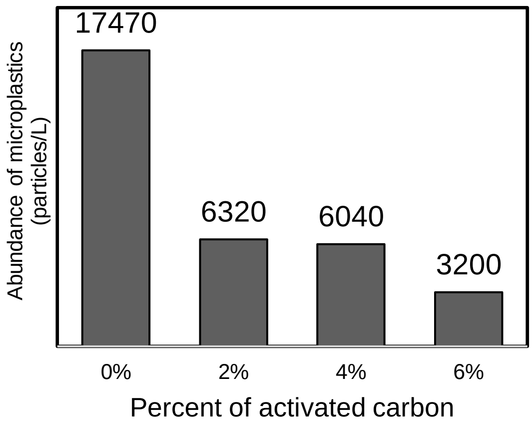


**Figure 4.** The effect of activated carbon percentage on the abundance of microplastics over 60 minutes

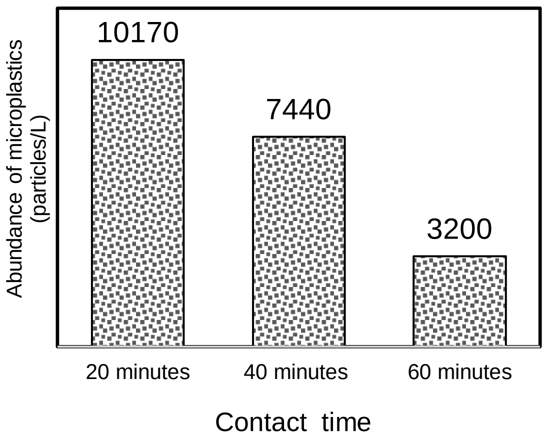


**Figure 5.** Effect of contact time of 6% activated carbon on the abundance of microplastics

## CONCLUSION AND SUGGESTION

The well water around the Piyungan landfill contains quite high levels of microplastic particles. The shape of microplastic particles consists of fragments, fibers, and filaments. This type of microplastic polymer in well water is strongly suspected to consist of polyethylene, polystyrene, and polyvinyl chloride. With a batch system, granulated activated carbon can be used to remove microplastics in well water. The decrease in microplastic content in well water is influenced by the amount of activated carbon adsorbent and contact time. The higher the amount of activated carbon and the longer the contact time, the higher the microplastic removal rate. Further work is necessary to study the optimization of adsorption techniques and conditions.

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