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# Effect of Flocculation and Sedimentation Times on the Removal of Polystyrene Microplastics from Water

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## EXTENDED ABSTRACT

### Introduction

Microplastics (MPs) are plastic particles and fibres < 5mm. They are generally hydrophobic and have relatively high surface area when they are in the smaller particle size range. Then, they have stronger ability to adsorb pollutants and could become a source of pollutants themselves [1]. Some microplastics have been found to cause oxidative stress in a number of aquatic organisms [2] and affect crop yields when they are in soil [3], which could have been polluted from adopting sludge from water treatment works. It has become apparent that effluents from wastewater treatment plants can release MPs into rivers and these particles may reach drinking water treatment plants [4]. Therefore, research on the removal of MP pollution from water is urgent.

Sedimentation and coagulation-flocculation have been traditionally used in drinking water treatment plants to decrease turbidity primarily. Indeed, MPs are part of the suspended matter that can increase turbidity. This study has focused polystyrene beads of 100 $\mu$m with density 1.04-1.06 g / cm$^3$, hence they offer a challenging scenario to study MP separation from water. Furthermore, this is the first time taht the PDA 3000, Phase Doppler Anemometry (Rank Brothers Ltd., Cambridge) (fig. 2) was used to monitor the microplastics removal process.

### Methods and materials

All chemical reagents used were analytical grade and obtained from Sigma-Aldrich (UK), including $Al_2(SO_4)_3$ (99.9% purity), 99.9% HCl, NaOH (analytical quality), kaolin and polystyrene (PS) beads (100 µm, 1.04-1.06 g / cm$^3$) of 10 mg/L were purchased from Dongguan Xingwang Plastics Co., Ltd. Water used in this research was from the Regent's Park lake, London (average characteristics: pH 8.4 ± 0.1, turbidity 0.8 ± 0.3 NTU, UV-254 0.64 ± 0.59 taken in January 2021.

A PB-900 programmable Jar tester (Phips & Bird, Richmond) was used with a total of 6 x 1L beakers. For the quantification of MPs, an optical microscope (model Euromex Oxion Material Science) and CountessTM cell counting chamber slides (C10228, Thermo Fisher Scientific, UK) were used for visually inspecting the MPs with microscopy. A 2100AN IS Turbidimeter (Sigma-Aldrich, UK) was used.

For the optimisation of the flocculation time, the following conditions were kept constant: $Al_2(SO_4)_3 \cdot 18H_2O$ 3.4 mg/L as Al, PS MP 10 mg/L, pH=5, stirring speed 50 rpm, coagulation time 60s, sedimentation time 30 min. The flocculation time changed from 100s to 800s to find the best removal rate in this research. For the optimisation of the sedimentation time, $Al_2(SO_4)_3 \cdot 18H_2O$ 3.4 mg/L as Al, PS MP 10 mg/L, pH=5, stirring speed 50 rpm, coagulation time 60s, flocculation time 400s were fixed. The sedimentation time was screened from 0 to 40 min.

**Results and Discussion**

This study has focused on 100 µm PS beads due to their toxicity [4] and because this polymer type and size is commonly found in effluents from clarifiers [2]. The duration of the flocculation affects the removal of suspended particles. From Figure 1, it can be observed that in the particular case of 100 µm PS beads spiked in natural water, when increasing the flocculation time to 400 s, or even longer, the removal went up to ~99%. After flocculation, sufficient sedimentation time will allow the suspended flocs to completely settle. This will avoid errors in the MP concentration measurements because smaller floating flocs in the water can be mistaken for MPs through turbidity measurements. In the specific conditions of this study, sedimentation time gradually increased until 40 min. Then the removal reached ~99% of MPs at 30 min (see Figure 1). After that, increasing sedimentation time did not lead to improvements in the removal of the study beads.

The study on the capacity of coagulation-flocculation and sedimentation on a single type of MP has allowed depth and greater detail in the removal conditions. The optimal conditions for the removal of 100 µm PS beads under the study conditions were found to be 3.4 mg $Al^{3+}$/ L, pH 5, flocculation time 400 s, sedimentation time 30 min. Under these conditions, and when natural water was used, percentage removals were ~99%. In the PDA result (fig. 2), the removal of PS 100µm beads after floc breakage and regrowth at 1000s reached 93.8%, i.e. 16% larger than traditional flocculation process (80.7%).

**Conclusions**

For the spiked 100 m PS beads in natural water, removals were ~99% with 3.4 mg $Al^{3+/}$ L, pH 5, coagulation speed at 400 rpm for 60s and decreased to 50 rpm stirring speed for 400 s flocculation time, and 30 min sedimentation time. Hence, the removal rates even with presence of organic matter in the water sample indicate that coagulation-flocculation and sedimentation can be key in delivering water with reduced levels of MPs. Future work should address how coagulation-flocculation-sedimentation conditions change over wider variety of MPs; and how these optimal conditions for MPs will be affected in the presence of organic matter and other suspended particles. It is necessary to investigate wider types of raw water and coagulants and give further insights of removal mechanisms that will make possible finding standard conditions for the removal of MPs that can be upscaled.

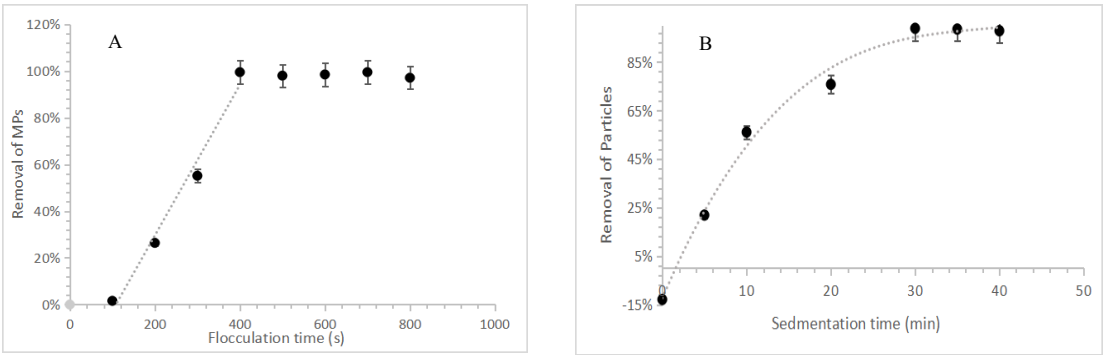


*Figure. 1 Effect of flocculation time (A) and sedimentation time (B) on the removal of 100 µm PS*

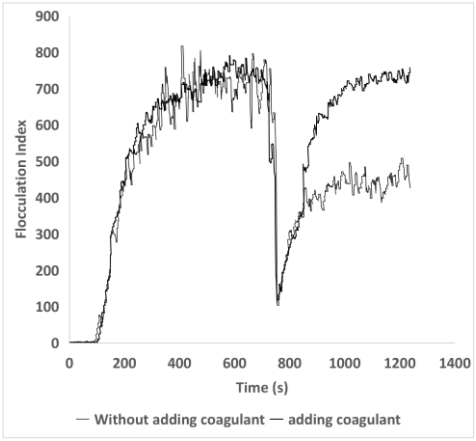


*Figure. 2 Effect of floc-breakage on MP's removal*

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