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Leachates from Recycled PET Plastic Concrete: Phytotoxicity and Characterization

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Abstract In the last two decades, several studies reported on plastic pollution worldwide in aquatic and terrestrial environments. Several past studies have presented plastic waste using concrete as one of the most promising solutions in plastic waste management. The most concerning part of using plastic waste in concrete as natural aggregate replacement present the deterioration of mechanical properties and increase of toxic impact in aquatic and terrestrial ecosystems. Therefore, research was done to determine the ecotoxicological potential of concrete in which 5% of recycled PET plastic replaced natural aggregate. A phytotoxicity test was performed according to ISO 20079:2005 using *Lemna minor*. Characterization of leachates used in phytotoxicity test was also made using ICP-OES. A comparison of inhibition of duckweed growth rate in conventional and PET concrete leachates showed no significant differences. The inhibition of growth rate in 100 g L^{-1} concrete leachates was significantly higher than in 0.1 g L^{-1} leachates. ICP-OES of concrete leachates showed no significant increase in the content of heavy metals. Based on the results of the phytotoxicity test and leachate characterization, PET concrete can be despite PET plastic content labeled as non-toxic to duckweed in aquatic environment. The presence of PET in concrete did not increase the toxic impact of concrete and its leaching behavior. Therefore, PET concrete presents an environmentally safe solution for plastic waste management and the conservation of natural resources by reducing natural aggregate consumption.

Keywords: concrete, ecotoxicity, leaching, natural aggregate, PET plastic

1. Introduction

In the last two decades, several studies reported on plastic pollution all over the world in aquatic and terrestrial environments (Ritchie et al., 2023; Rhodes, 2018). Saikia and de Brito (2012) presented plastic waste use in cement mortars and concrete as one of the most promising solutions in plastic waste management. The most concerning part of plastic in concrete present the deterioration of mechanical properties of such new materials. Decrease in fresh density and decrease in compressive, and flexural strength compared to conventional concrete were reported. Therefore, the optimal percentage of plastic as natural aggregate replacement in concrete is crucial. According to the past studies, 5% of plastic as replacement in concrete presented the maximum dosage, with no significant impact on deterioration of mechanical properties. While plastic use in concrete present a promising solution for plastic waste reduction, it raise a concern due to ecotoxicological properties of such new materials. Several studies reported about the migration of microplastic from PET plastic into the water and soil, and confirmed the leaching of various substances (antimony, phthalates) from PET particles into the environment (Dhaka et al., 2022).
Therefore, the main purpose of our research was to determine leaching behavior and ecotoxic potential of recycled PET plastic in concrete as partial natural aggregate replacement.

2. Materials and Methods

Recycled PET plastic particles with diameter of <4 mm were used as 5% replacement of the volume of natural aggregate in concrete. After removal from the 10 cm cube moldings, hardened concrete samples were stored in water for 28 days. After 28 days, conventional and PET concrete were grinded.
Leaching process of PET concrete started with preparation of Steinberg medium according to ISO20079:2005. A weighted amount of grinded concrete (100 mg and 100 g) was then added to 250 mL Erlenmeyer flask and Steinberg medium. Flasks were covered with parafilm, left on the shaker for 24 h (100 g L^{-1} concrete leachate) and 168 h (0.1 g L^{-1} concrete leachate), and then filltered. Prepared concrete leachates were analysed using ICP-OES and used in ecotoxicity test with *Lemna minor*.
Lemna minor (duckweed) ecotoxicity test was performed according to ISO 20079:2005. First, 50 mL of concrete leachate and 10 fronds of *Lemna minor* were added in each flask, which were then covered with parafilm and kept under controlled conditions for 168 h (16 h light/8 h dark). After 168 h, the growth rate inhibition of duckweed was determined.

3. Results and Discussion

168 h duckweed test results are presented in Figure 1. It was found that the 0.1 g L^{-1} conventional and PET concrete leachate promoted the growth of duckweed fronds by 11% and 9%. Oppositely, both 100 g L^{-1} concrete leachates inhibited duckweed frond growth. The inhibition value in 100 g L^{-1} conventional leachate was around 45%, while the inhibition value in PET concrete leachate was approximately 10% higher. Presented large standard deviations in all the leachates indicate that differences between conventional and PET concrete leachates were negligible. Based on these results, it can be assumed that there is no significant difference in the ecotoxicity of conventional and PET concrete leachates. Further ICP-OES analysis of concrete leachates presented in Figure 2, revealed concrete leachates had up to 5 times higher calcium content than the duckweed growth medium. Potassium and sulfur content in concrete leachates was comparable to the content in duckweed growth medium. A significant increase in Ca was expected due to its presence in cement and natural aggregates. However, it can be assumed that this increase did not contribute to inhibition of duckweed frond growth and additional analyses need to be done to confirm that with greater certainty.

4. Conclusions

Regarding the results, the presence of PET plastic in concrete did not increase the inhibition value of duckweed frond growth compared to conventional concrete. Additionally, PET and conventional concrete leachates did not cause a significant decrease in duckweed frond growth. This indicates that PET concrete can be presented as a non-toxic material in the environment.

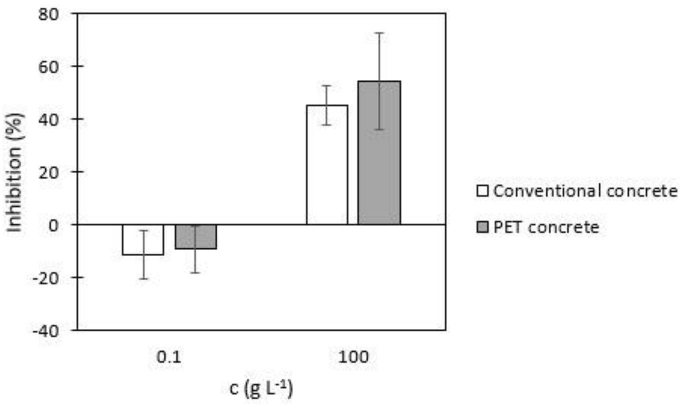

Figure 1. *Lemna minor* growth rate inhibition.

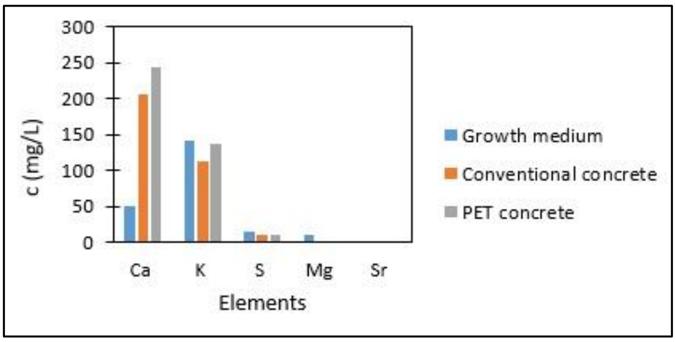

Figure 2. ICP-OES analysis of concrete leachates.

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