Terrestrial ecotoxicity of green concrete containing PET plastic waste

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Introduction

Plastic waste represents one of the most pressing environmental challenges of the 21st century. Among the various types of plastics, PET (polyethylene terephthalate) is particularly problematic because it is widely used, rapidly discarded, and accumulates in the environment at an alarming rate. In recent years, researchers and industry professionals have increasingly explored the possibility of incorporating waste PET into concrete as a partial replacement for natural aggregates. This approach is motivated by the enormous scale of global concrete production, which exceeds 30 gigatonnes per year (Abubakar et al., ,2024; Ahmed and Abdulqudos, 2024; Askar et al., 2023). Since aggregates make up roughly three-quarters of the volume of concrete, even replacing a small fraction of natural aggregate with recycled PET could significantly reduce the amount of PET waste entering landfills and natural ecosystems (Bamigbove et al., 2021).

However, this promising solution also raises important environmental concerns. One of the key questions is what will happen to such PET-containing concrete once it reaches the end of its service life and becomes construction and demolition waste. Unlike conventional concrete, this material contains embedded plastic particles that may behave differently during degradation. As the concrete weathers, breaks down, or is crushed for recycling, there is a possibility that PET fragments or microplastics could be released into the environment (Ahmed and Abdulqudos, 2024).

Additionally, PET can leach various chemical compounds, especially when exposed to mechanical stress, UV radiation, or fluctuating pH conditions. These substances may have harmful effects on organisms across different ecosystems, including soil microorganisms, aquatic species, and even higher trophic levels. The long-term environmental impact of such leaching processes remains insufficiently studied, raising concerns about whether the benefits of recycling PET into concrete might be offset by unintended ecological consequences.

Therefore, while the incorporation of PET waste into concrete offers an innovative pathway toward reducing plastic pollution, it also highlights the need for comprehensive environmental assessments, long-term durability studies, and responsible end-of-life management strategies

Materials and Methods

Conventional and green concrete with water-to-cement ratio of 0.45 were prepared. At the age of 28 days, the hardened concrete samples were grinded. The resulting grinded concrete particles were used for leachate preparation. The growth medium was prepared according to procedures described in previous studies (Beklová et al., 2010; Fargasova, 2004). Leachates were prepared using concrete particle concentrations of 0.1 g L^{-1} and 100 g L^{-1}. The leachates with a concentration of 100 g L^{-1} were prepared in accordance with the standard EN 12457-4:2002 (Characterisation of waste – Leaching – Compliance test for leaching of granular waste materials and sludges).

Prior to the mustard seed germination test, concrete particles were removed by filtration using black ribbon. For the germination test, a filter paper was placed at the bottom of a Petri dish, onto which 3 mL of leachate was added. Mustard seeds were then placed on the moistened filter paper. The Petri dish was covered and incubated in complete darkness for 72 hours. After incubation, the root lengths of the mustard seedlings were measured.

Results and Discussion

The graph in Figure 1 presents the impact of concrete leachate concentration on root length inhibition (%) in mustard seed germination tests, comparing conventional concrete and green concrete containing PET plastic. Two concentrations were tested: 0.1 g L^{-1} and 100 g L^{-1}.

At the lower concentration (0.1 g L^{-1}), conventional concrete caused a 7% root length inhibition, indicating mild suppression of root growth. In contrast, green concrete with PET plastic showed a negative inhibition of around -15%, meaning it actually stimulated root growth rather than inhibiting it. This suggests that at low concentrations, green concrete leachates may have a less toxic or even beneficial effect on root development compared to conventional concrete.

At the higher concentration (100 g L^{-1}), both types of concrete exhibited positive root length inhibition, indicating toxicity. Conventional concrete showed a stronger inhibitory effect (Figure 2), with root length reduced by about 17%, while green concrete with PET plastic caused a slightly lower inhibition of around 12%. Although both materials negatively affected root growth at high concentrations, the PET-containing concrete appeared to be less harmful.

Error bars on each bar indicate variability in the measurements, suggesting that while trends are clear, there is some uncertainty in the exact values. Overall, the results imply that incorporating PET plastic into concrete may reduce its phytotoxicity, especially at lower concentrations.

Figure 1. Results of mustard seed germination test.

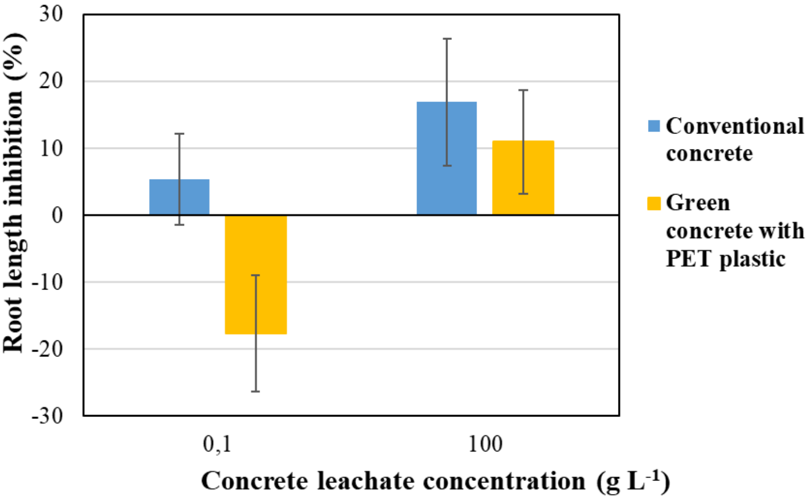

Figure 2. Mustard seed roots after germination test in 100 g L^{-1} concrete leachates.

Conclusions

The results show that PET-modified concrete generally exhibits lower phytotoxicity than conventional concrete, particularly at low leachate concentrations where it even stimulated root growth. At high concentrations, both concretes inhibited root development, though the green concrete remained less harmful. These findings suggest potential environmental advantages of incorporating PET into concrete, but at the same time both concretes at higher concentrations pose a risk to plant development in terms of germination. The need for comprehensive assessments of long-term ecological impacts before broader application of such green concrete was highlighted in this study.

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