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Deployment of Recyclable Polycarbonate as Alternative Coarse Media in Dual-media Rapid Filters

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Abstract

Sand and anthracite coal/granular activated carbon are commonly employed in traditional dual-media rapid filters to remove physical impurities present in influents. With increasing emphasis on sustainability, more water treatment facilities worldwide are opting for the use of eco-friendly materials which include recycled crushed glass, wood chips, and coconut shell based carbons. For instance, some filtration facilities of private pools in the United States have adopted recycled glass and obtained high quality effluent. The deployment of eco-friendly filter media in rapid filters deserves attention. In this study, sewed polyester bags which contained recyclable polycarbonate pellets (RPCs) were deployed as an alternative coarse media in a lab-scale dual-media rapid pressure filter setup. By coupling RPCs with sand, the following performance criteria were attained during the experimental runs when compared with the traditional dual-media: (a) similar rate of head loss development while maintaining acceptable effluent quality, and (b) improved clogging distribution within the filter. Life-cycle analysis (LCA) was also carried out with the Gabi Education software to assess the environmental footprint associated with various dual-media combinations. It is hopeful that the obtained LCA results would provide useful insights to industrial decision-makers who wish to improve the company's environmental performance index.

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Keywords: dual-media rapid filters, eco-friendly filter media, life-cycle analysis

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1. Introduction

Dual-media rapid filter technology is extensively employed as the pre-treatment step in many medium- and large-scale desalination plants worldwide. Some examples are the 250,000m^3/day Sydney Water plant in Australia, the

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200,000m^3/day Hamma plant in Algeria, and the 320,000m^3/day Ashkelon plant in Israel [1]. In dual-media rapid filters, fine sand and coarse anthracite coal/granular activated carbon (GAC) are commonly used as the dual-media combination for treating influents by physically removing its impurities [2]. However, the extraction of sand and anthracite coal in bulk quantities can lead to adverse effects to the environment. For example, the mining of anthracite coal results in acid mine drainage, land disturbance, upset of biodiversity and emissions of air pollutants from operational machineries [3]. Similar detrimental effects have also been reported for sand excavation [4]. Thus, reducing the reliance on these filter materials would improve the environmental performance of pre-treatment facilities. The use of recyclable materials is one possible avenue to achieve the objective.

With increasing emphasis on sustainability, the development of eco-friendly filter media is gaining popularity. Aksogan et al. (2003) demonstrated that higher turbidity removal efficiencies were achieved using crushed apricot shells combined with sand, when compared to the traditional dual-media. Additionally, the crushed apricot shells minimized the degree of intermixing with the sand layer during filter backwashing. The analysis was, however, incomplete with no mentioning of the head loss development rate [5]. Till date, there have been limited studies on the deployment of recycled materials in rapid granular filtration. Xie (2005) filed a patent on the use of rubber scrap from recycled tires as an alternative filter material. The novel media performed similarly to the conventional dual-media in terms of its turbidity removal efficiencies, even under high hydraulic loading rates. Furthermore, the compressible nature of the media resulted in a slower rate of head loss development and greater depth filtration [6]. Soyer et al. (2013) demonstrated that crushed recycled glass is a viable alternative for treating raw waters with low turbidity (6NTU to 14NTU). Higher quality filtrate and lower head loss were attained using crushed glass and anthracite coal combination. However, their study did not evaluate the replacement of anthracite coal with crushed recycled glass [7].

This study aims to evaluate the suitability of recycled polycarbonate pellets (RPC) as an alternative coarse media to the traditional anthracite in a typical dual-media rapid filter. The engineering novelty involved was the coupling of the RPC with sand (PC configuration), which did not fulfil the recommended uniformity coefficient and effective sizes deployed in traditional dual-media rapid filters. The assessment of the alternative dual-media was compared to the traditional dual-media based on the following criteria: (a) effluent point turbidity and (b) rate of head loss development. A series of experiments were carried out in attempts to achieve the study's objective. Additionally, the environmental burdens associated with the proposed configuration was analysed using a life cycle analysis (LCA) tool, and subsequently also compared against that of the conventional dual-media (DM configuration).

Nomenclature

d_{10}	10^{th} percentile of grain diameter, i.e. effective size
d_{50}	Median grain diameter
SG	Specific gravity
UC	Uniformity coefficient

2. Methodology

2.1. Rapid filtration experiments

Rapid filtration experiments were conducted in a lab-scale pressurized down-flow column, as schematically represented in Figure 1. The physical properties of the deployed dual-media (combination of sand and anthracite, sand and RPCs) are summarized in Table 1. It is worth noting that the physical shape of RPCs appeared to be highly homogeneous with an elliptic cylindrical shape having average dimensions of 3.0mm height, 3.0mm and 2.0mm ellipse axis. During the preparatory stage, the RPCs were packed into sachets made of polyester mesh with average dimensions of 75mm ×75mm× x15mm.

Before the start of each experimental run, 440L of tap water was added into the influent tank and mixed thoroughly with a specific mass of 20μm or 50μm particulate matter, Polyamide Seeding Particles, to emulate