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Review

Stormwater quality management in rail transportation — Past, present and future

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HIGHLIGHTS

- Stormwater management in the railway industry focused solely on drainage.
- Stringent stormwater quality standards require urgent responses from the industry.
- Railway transportation generates potential sources of pollutants for runoff.
- Urban retrofitting provides opportunities for railway stormwater management.

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ABSTRACT

Railways currently play an important role in sustainable transportation systems, owing to their substantial carrying capacity, environmental friendliness and land-saving advantages. Although total pollutant emissions from railway systems are far less than that of automobile vehicles, the pollution from railway operations should not be underestimated. To date, both scientific and practical papers dealing with stormwater management for rail tracks have solely focused on its drainage function. Unlike roadway transport, the potential of stormwater pollution from railway operations is currently mishandled. There have been very few studies into the impact of its operations on water quality. Hence, upon the realisation on the significance of nonpoint source pollution, stormwater management priorities should have been re-evaluated. This paper provides an examination of past and current practices of stormwater management in the railway industry, potential sources of stormwater pollution, obstacles faced in stormwater management and concludes with strategies for future management directions.

Contents

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1. Introduction

Among the many endeavours of society to promote a sustainable transportation system, railway networks play a crucial part because of their substantial carrying capacity. A rough statistic from the World Bank (2014) showed that the combined length of the world's railway lines increased dramatically by 40% from 1990 to 2012. Compared to roadway transport, railway is considered more environmentally friendly in providing mass transporting services with less negative ecological impact (Zimmerman, 2005). Nonetheless, the environmental benefits from railway transportation over private vehicles are undeniable.

Hence, railway networks are likely to be upgraded in order to meet greater transportation and environmental demands (Kamga and Yazici, 2014; Zhiqun and Jiguang, 2011). Although emissions from railway systems are far less than that of automobile vehicles, the environmental pollution from railway operations should not be underestimated. Frequently mentioned types of impact caused by rail transportation include noise (Aasvang et al., 2007; Ali, 2005; Trombetta Zannin and Bunn, 2014), vibration (Kouroussis et al., 2014; Sanayei et al., 2013) and air pollution (Dincer and Elbir, 2007; Salma et al., 2009). In contrast, there have been very few studies into the impact on water courses. This lack of interest does not imply that water pollution from the railway industry is an insignificant issue. As Osborne and Montague (2005) stated, "railway operations, both current and in the past, have the potential to give rise to pollution, as water drains from the railway into water courses". Yet, to date, priorities in water management for rail tracks still solely focus on its drainage function. Hence, upon realising the significance of nonpoint source pollution, stormwater management priorities should have been re-evaluated. This paper will provide an examination of past and current practices of stormwater management in the railway industry, potential sources of stormwater pollution, management obstacles and future directions.

2. Conventional approach to stormwater management in the railway industry

Rail tracks and supporting systems attracted the most attention in stormwater management plans for the railway industry as they were the backbone of railway services. This heightened attention was due to the negative impact of runoff on rail tracks directly threatening rail safety.

Based on the track support systems (or substructures), rail tracks are divided into three categories: traditionally ballasted, modified ballasted and ballastless. Configurations of these substructures were well presented in the works of Esveld (1997) and Teixeira et al. (2009). While the latter types of rail tracks developed due to demands for high-speed trains and low maintenance frequency, ballasted railway tracks have still been employed extensively, thanks to their enormous economic advantages. A typical ballasted substructure comprises of a top ballast layer (150–550 mm of single-sized rocks), a sub-ballast layer (90–450 mm of well-graded crushed rock or a sandy gravel mixture) and an underlying subgrade layer (natural or amended soil). Each layer performs different structural functions to ensure the durability and stability of a rail track. Precipitation falling on ballast quickly drains to the sub-ballast layer and then runs into drainage systems. The drainage system could be either a parallel pipework network or a natural ditch, which is located along the sides of the embankment toe. Similar mechanisms were found in depots or maintenance centres. The influence of runoff from surrounding areas on the rail track areas is often restricted to ensure the safety of the track bed.

The effect of runoff volume on rail tracks was investigated thoroughly, as the saturation of water in these layers can reduce the stiffness of the track foundation (Australian Rail Track Corporation Ltd., 2006). The flow hydraulic properties vary depending on the type and age of the track bed. Drainage capacity of a track decreases over time, as sediments accumulate in its body (Burkhardt et al., 2005).

Rushton and Ghataora (2014) observed that greater impact occurred when water accumulated in the sub-ballast and subgrade layers, where finer grains were predominant. Under the load of moving trains, trapped water became pressurised, drawing clay or silt from the subgrade upward to the ballast layer, known as the "clay pumping" phenomenon (Rushton and Ghataora, 2009). Together with the depositing of dust and abrasive materials on the ballast surface, clay pumping can cause ballast fouling (Indraratna et al., 2011). The fouled ballast further degraded the drainage capacity of the track support system and led to structural deformation. Due to its high risk of rail track structural deformation, stormwater was a critical problem for rail operation. Stormwater runoff had subsequently been perceived as a nuisance that must be drained as quickly as possible.

For modified ballasted systems (with a bituminous or geotextile layer working as the sub-ballast layer) and ballastless systems, the effects of stormwater on the foundation structure are less severe. EAPA (2003) pointed out three main reasons for this improvement. Firstly, an asphalt layer distributed train loadings more uniformly, hence