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Pollution level and reusability of the waste soil generated from demolition of a rural railway☆

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A B S T R A C T

Railways are typically considered polluted from years of train operation. However, the pollution level of railway in a rural area, which is less exposed to hazardous material from trains and freights, is rarely assessed. This study evaluated common railway pollutants such as heavy metals, total petroleum hydrocarbons (TPHs) and polycyclic aromatic hydrocarbons (PAHs) and their chemical properties in the waste soil generated from the renovation of an old railway in rural area of Wonju, South Korea. Furthermore, lab-scale cultivation tests of peas (*Pisum sativum*) were performed to assess reusability of the waste soil as a soil amendment. Carbonaceous materials were found in the upper layer of the railway (0 to −40 cm) and the concentration of common railway pollutants was comparable to those of the agricultural land nearby. Specifically, total aromatic and aliphatic TPHs were below detection limit; and total PAHs < 1.0 mg kg^{-1} was 1000-times less than railway functional parts. Applying the carbonaceous waste soil improved the water holding capacity of soil by approximately 10% and sprouts formed on the soil with 10% waste soil composition had greater fresh weight, stem length, and root length than the control. Although this investigation was confined to a small length of the railway route, the results confirm environmental safety and the potential value of the waste generated from rural railways for the first time.

1. Introduction

Every year, over 1,000,000 km of railroads carry billions of people and cargo around the world (UIC, 2012). In 2015, the US spent $ 64.9 billion on the operation, maintenance and modernization of this resource-efficient transport system (AAR, 2016). Likewise, South Korea plans to invest $ 48 billion on 5000 km of rail network by 2020 (KR Network, 2015). Railway projects (both large and small) generate a substantial volume of construction and demolition (C&D) waste such as sleepers, ballasts and sub-base soil, and can raise significant environmental concern. The three strategies in the waste management are to reduce, reuse and recycle before disposal (Yuan and Shen, 2011). However, authorities strictly limit reusing the C&D waste as they are often highly polluted (Korea Ministry of Environment, 2017; Government of South Australia, 2015).

Previous studies confirmed the accumulation of petroleum product, heavy metals and other hazardous material in railways (Vo et al., 2015). The typical detection of pollutants has conducted towards the negative perspective of railways as a threat to environmental safety. Furthermore, most of these investigations focused on functional parts, such as transport junctions, train depots and train stations which are regularly exposed to people, frights and maintenance works that make them prone to pollution (Wiłkomirski et al., 2011; Zhang et al., 2012). In contrast, rural railways, which are a major constituent of a rail network with a lower probability of pollution, are rarely evaluated for hazardous material. Overall, the conclusion made based on the partial observation from polluted areas may not accurately reflect the condition of railways in general. Furthermore, to the best of our knowledge, no studies have assessed the reusability of the C&D waste generated from a rural railway.

The sub-base soil of an abandoned railway has been reported alkaline with organic and inorganic matters, which supports plant growth (Wiłkomirski et al., 2011). Thus, the environmental and financial burden associated with the disposal of the railway waste

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soil may be reduced by reusing them for land reclamation or agriculture. Both biological and physicochemical treatments can remediate pollutants in the waste soil. Nevertheless, clean-up standards are difficult to meet using biological means within a typical construction schedule because of their slow treatment processes (Balba et al., 1998). Physicochemical methods can rapidly stabilize organic matters and immobilize heavy metals (Maroušek et al., 2015), but these methods are impractical for handling a large volume of the waste generated daily. Thus, reusing railway waste soil have had been impractical, however, it may be possible to reuse them without conditioning if the physicochemical characteristic and pollution level can ensure environmental safety.

This study evaluated the pollution level of the waste soil generated from the renovation site of an old railway in the rural area of Wonju, South Korea. The chemical properties, heavy metals, total petroleum hydrocarbons (TPHs) and polycyclic aromatic hydrocarbons (PAHs) were measured at different depths of the rural railway and compared with those of nearby agricultural land. Furthermore, the reusability of the waste soil as a soil amendment was tested through a lab-scale cultivation test using peas (*Pisum sativum*).

2. Materials and methods

2.1. Collection of soil samples

Experimental samples were collected from three locations (Fig. 1) along the Seoul-Wonju Railway Route Renovation Project site in Wonju, South Korea (37°21′51.1″N 127°54′43.1″E). The old ballast structure consisted of three different layers of rock and sand (Fig. 1, Fig S1A). The top layer was 30 cm of track ballast (L_{top}), the middle layer was 10 cm of sandy-loam (L_{mid}) and the bottom layer was sub-base soil (L_{bot}). The L_{top} and L_{mid} showed signs of fouling (Fig. S1B), whereas the L_{bot} was similar visually to the soil sampled from an agricultural land 100 m away from the project site (CN). Samples collected from each layer and the agricultural land were passed through a 2-mm sieve to obtain useful agricultural soil for subsequent tests (herein after the soil isolated from L_{top}, L_{mid} and L_{bot} will be collectively and individually referred to as the "waste soil").

2.2. Analysis of chemical properties

Chemical properties, including pH, oxidation-reduction potential (ORP), dissolved organic carbon (DOC), loss on ignition (LOI), plant nutrients (total nitrogen [TN], phosphorous [TP] and K) and trace elements (total Fe, Mn, Zn, Na, Mg and Ca) were measured as the soil fertility indicator. Extractable heavy metals (total Al, As, Cd, Cr, Cu, Ni and Pb), total petroleum hydrocarbons (TPHs) - aliphatic and aromatic, and polycyclic aromatic hydrocarbons (PAHs) comprising 16 priority species listed by the United States (US) Environmental Protection Agency (EPA) were measured as the common railway pollutants. Each test was done in triplicates and repeated twice.

The pH and conductivity of a 1:5 soil:water solution was measured with a pH meter (Orion Star A211, Thermo Scientific, USA). The DOC was determined using a TOC Analyzer (Shimadzu, Japan) and the loss on ignition (LOI) was determined by LOI/Volatile Solids Total Organics-Gravimetry (Korea Ministry of Environment, 2009). The TN was measured by the Kjeldahl digestion procedure (Gallaher et al., 1976). The TP, in the form of PO_4^-, was determined using the vanadomolybdophosphoric acid colorimetric method.

The extractable trace elements (including K) and heavy metals were measured by analyzing filtrates of the soil solution using an Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES; ICP/IRIS, Thermo Jarrell Ash Co., USA). The filtrates were

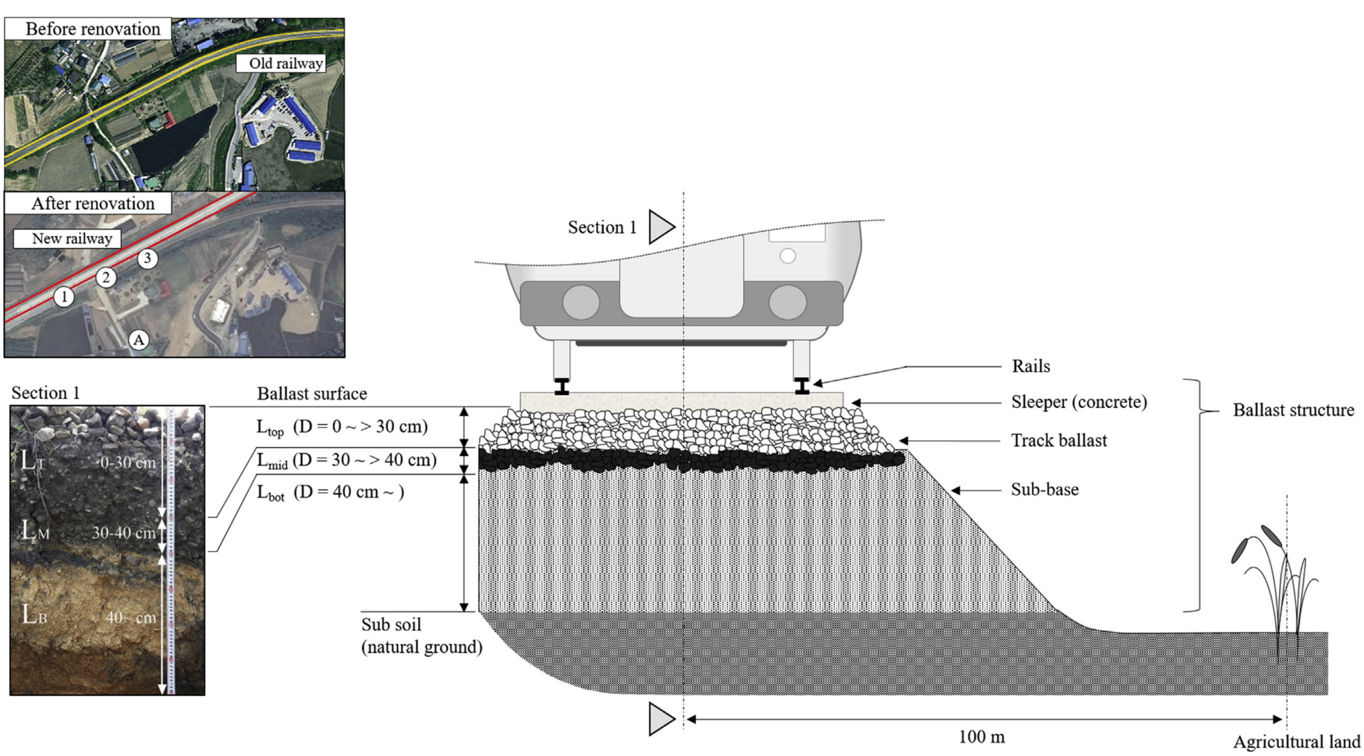

Fig. 1. Cross-sectional view of the investigated railway in a rural area of Wonju, South Korea, with typical constituents of a ballast structure. Section 1 shows clear separation of the top (L_{top}), middle (L_{mid}) and bottom (L_{bot}) layers as well as the carbonaceous material found in the L_{top} and L_{mid}. Numbers 1, 2, 3 and the letter A mark the three different sampling locations for the waste soil and agricultural land, respectively.