

Characteristics of organic carbon in soils and the removal of chromium (VI) from soil leachate using zero-valent magnesium

Chul-Min Chon, Jae Gon Kim, Jung Hwa Lee, Yong-Chan Cho, and In-Hyun Nam

Korea Institute of Geoscience and Mineral Resources, Geologic Environment Division, Korea, Republic Of
(femini@kigam.re.kr)

Hexavalent chromium [Cr(VI)] is hazardous because it has high mobility, toxicity, and strong oxidizing properties. In comparison, trivalent Cr(III) is less toxic than Cr(VI) and relatively immobile in soils and sediments, owing to its extremely low solubility. The oxidation state of Cr in soils is mainly determined by organic matter, manganese oxides as oxidizing agents, and Fe(II)-containing minerals as reducing agents. We collected 31 samples of the residual soil from representative geological bedrock in Korea and characterized them physicochemically. Sixteen soil samples were artificially contaminated with 100 mg Cr(VI) per kg of soil to examine the removal of Cr(VI) from the soil leachate using zero-valent magnesium (ZVMg). To evaluate the organic carbon (C) content, the loss on ignition (LOI), total C, and active C contents were determined using two dry combustion methods (the ignition loss and elemental analysis methods) and a wet oxidation method (potassium permanganate method). Active C is the soil carbon with unstable bonds that easily decompose, and was measured to estimate the organic C fraction that is sensitive to the Cr redox reaction in the soil. Active (labile) organic C is the portion of the soil organic C that is readily decomposed by soil organisms and is measured via a chemical oxidation method using potassium permanganate. The soil pH, total Mn, total C, LOI, and active C contents of the samples ranged from 4.90–7.39, 0.02–0.67 wt%, 2.17–10.77 wt%, 2.42–21.55 mg/g, and 0.26–3.09 mg/g, respectively. There were very weak positive correlations between LOI and the total and active C contents, with $R^2 = 0.11$ and $R^2 = 0.21$, respectively. By contrast, the correlation between the total and active C contents was strongly positive, with $R^2 = 0.82$. The wet oxidation method can overestimate the organic matter content in samples containing large amounts of reducing materials, such as sulfide minerals, but tends to be underestimated in samples containing non-biodegradable organic constituents, such as humic substances. The determination of the organic matter content based on LOI can be overestimated due to the removal of hygroscopic and intercrystalline water from clay minerals, water loss from hydroxyl groups in (oxy)hydroxides, and CO₂ release from carbonates. The mineral composition analysis confirmed a significant difference between the total C and LOI methods in samples with high clay mineral contents, such as kaolin and mica. These results indicate that a systematic, quantitative understanding of the soil organic C content is essential for the development of Cr(VI) removal technology using redox reactions in the soil environment. The removal efficiency of Cr(VI) from the soils ranged from 48.6% to 93.0% (average 75.0%) at a ZVMg dose of 0.04 g/g soil. We confirmed that ZVMg can be used to remove adsorbed Cr(VI) and water-soluble Cr(VI) from contaminated soils. The reduction mechanism of Cr(VI) from contaminated soil using ZVMg was related to Mg solubility, the chemical species of Cr(VI) in soil, and the physicochemical properties of soil, such as the soil pH, EC, and mineralogical characteristics.