Enhanced humification of soil organic matter by microwave irradiation and hyperthermal catalysts

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Soil organic matter (SOM) is derived from dead biomass of animals and plants, and its formation process in which the precursor materials of SOM are transformed into macro organic molecules through geo-chemical and geo-biological reactions in the subsurface environment is referred to as humification. Carbon content increases, but oxygen content decreases along with marked increased in molecular weight and degree of condensation of SOM during humification. As illustrated in figure 1, it has been known that humus materials evolve in the order of biopolymer, fulvic acid, humic acid, and humin. Humification process takes place in a geological time scale, but it can be accelerated at extremely high temperatures, which can be achieved by microwave (MW) with hyperthermal catalysts (HTCs). Thus, MW was irradiated to the mixture of soil and HTCs to stimulate humification of SOM and to enhance its binding capacity for recalcitrant organic contaminants in this study. MW irradiation with HTCs was optimized, and the characteristic changes of SOMs before and after the irradiation were assessed to confirm humification. Soils were collected from 4 different forest regions in Seoul, Korea (Konkuk University, Yongma Mountain, Surak Mountain, and Bukhan Mountain), and they were screened by wet-sieving. Each component of SOM was isolated by acid-base extraction/selective exchange resin, which was proposed by the International Humic Substance Society. Total organic carbon (TOC) content, specific ultraviolet absorbance (SUVA), E4/E6 ratio, and Fourier transform-infrared spectroscopy (FT-IR) spectrum of SOM before and after MW irradiation were examined. Soil of Surak Mountain exhibited the highest organic carbon content, but Yongma Mountain contained the highest amount of fulvic acid (figure 2). Soils of Yongma Mountain and Konkuk University were chosen due to their high fulvic acid content, which supported that these soils are relatively geologically-young soils. Powdered and granulated activated carbon (PAC and GAC), graphite, charcoal, and carbon nanotube (CNT) were selected and screened with regard to their hyperthermal activity under MW irradiation. The temperature changes by MW with HTCs were monitored at various MW irradiation intensity and time. Graphite- and CNT-soil mixtures exhibited the optimum heating capacity at 600 W, resulting in heating HTC-soil mixtures to approximately 1,000ºC within 10 min. TOCs, SUVAs, E4/E6 ratios, and FT-IR spectra of SOM supported effective humification of SOM after MW irradiation with HTCs, and notable increase in binding capacity with hydrophobic organic contaminants. The results of this study are expected to provide the fundamental information for developing the performance-efficient and cost-effective treatment process for the removal of persistent organic contaminants based on MW and HTC.
[Figure 1] SOM evolution

[Figure 2] Organic carbon contents of SOM