Physicochemical Properties of Nanoparticles in Red Soils Determined by EXAFS Techniques

Ming-Kuang Wang (王明光)

Department of Agricultural Chemistry, National Taiwan University, Taipei, Taiwan

Over the past two to three decades, nanoparticle research and development have brought a significant breakthrough in many areas of pure and applied sciences. There has been a great deal of evidence indicating that inorganic and organic colloid particles (1–1000 nm) in natural systems such as soils, earthquake-generating faults, groundwater, streams, rivers, lakes and oceans, as well as in the atmosphere play an important role in the circulation processes of nutrients and pollutants. In particular, nanominerals and mineral nanoparticles in the environment have been present throughout the evolutionary development of hominids; and our exposure to these through inhalation, ingestion, and dermal pathways are important foci of nanotoxicology.

The red soils developed are not known due to lack of proper dating tool for the quaternary deposits and dynamic systems of red soils. On the other hand, the limitation of separation of finer particle sizes of clays in Oxisols still remained obscured due to the bottle neck of separation techniques. Therefore, information on the red soils, formational mechanism and physicochemical properties of inorganic nanoparticles is severely lacking. We have to demonstrate that these fine nano-particles easily leached out during pedogenesis. Thus, the desilication in fine particle sizes and enrichment in sesquioxides in red soil developments should be related the concept to soil weathering. Fine particle sizes removed or leached more Si and enriched Al and Fe in coarser particle sizes to develop red soils in acidic soil environments. This study aimed on investigation and characterization of finer particle sizes, including the nanoparticles (< 100 nm) in red soils at Linkou, Taoyuan and Chinmen areas.

An unpolluted surface (0-20 cm) of the Linkuo red soil in northern Taiwan was collected from a farm for this study. The clay fractions (< 2000 nm) suspended in double deionized water, dispersed by ultrasonification at 170 watts and 60 kHz for 1 min, by NEY 300 Ultrasonic. The suspension was then passed through a sieve (300 meshes per inch, aperture 50 μm) to remove the sand fraction from the suspension of dispersed mineral particles by wet sieving. Then the < 2000 nm particle size fraction was collected by sedimentation according to Stokes' Law. The time required to separate this fraction into the size range of 450–2000, 100–450, and 1–100 nm size fractions were calculated by the modified Stokes' equation and filtration methods by automated ultrafiltration devise.

From the results of Lab XRD analysis, the X-ray diffractograms of K-saturated clays (< 2000, 450-2000, 100-450 nm) and nanoparticles (50-100 nm) at 25°C showed a 1.01, 0.71, 0.51, 3.51, 0.334 Å d-spacing values (no shown). In the K-saturated clays and nanoparticles heated at 110°C and 550°C, the *d*(001) peaks of illite at 1.01 (001), 0.51 (002) and 0.334 (003) still remained in XRD patters. However, the *d*(001) peak at 0.71 Å was not observed after heating the K-saturated clays and nanoparticles at 550°C, indicating kaolinte is present in clay and nanoparticle fractions. There was no peaks were detected in 1-50 nm size fraction by XRD analysis, indicating nocrystalline nanoparticles. In XRD diffractograms of < 2000 and 450-2000 nm, 4.26 and 3.34 Å of quartz XRD peaks are present in coarse clay fractions. There are present a 4.16 Å of goethite *d*(110) XRD peak in the < 2000 and 450-2000 nm clay fractions. Al-substituted goethite may cause XRD peak shifted from 4.18 to 4.16 Å.

Comparing the results of 01C2 powder X-ray diffraction, in the nanoparticles, XRD patterns show the illite, geolite and kaolinite exist in the finer sizes of red soils (see figure). TEM images also show the present of illite, geolite and kaolinite, because of geolite is below to 5 to 15 nm in size (see TEM), indicating that Lab XRD analysis can not identify the present of geolite. Significant expansion occurred in 100-450 nm size fraction, sex XRD peaks of quartz present in fine particle-size fractions (see figure). The 01C2 powder X-ray diffraction has facilitated research on the mineral species identification of nanoparticles by comparison of Lab XRD analysis.