Scientific correspondence

Nanocrystalline silica from termitarium-soil-system: a note on newer dimensions

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Nature uses both inorganic and organic components to achieve desirable mechanical properties in a material that can be formed under ambient conditions. The inorganic components tend to be limited to a few minerals such as phosphates, carbonates and silicates. The silicates materials combine oxygen and silicon, the two most abundant elements in Earth's crust. A common silicate is silica, SiO$_2$, which is found both in biological settings and in man-made materials such as cement and everyday glass. Silica has a rich chemistry that can be adapted to obtain a variety of structures (Iler, 1979; David, 2007).

Rightly decade back (Paul, 2004), it was predicted that the ability to sense and detect the state of biological systems and living organisms optically, electrically and magnetically will be radically transformed by developments in materials physics and chemistry. Use of nanomaterials in biological systems, in particular the too complex termite-soil-system is an emerging and welcome event, that can integrate frontier science in termite R&D, enabling diversity of experiments, as well as better crosschecks and controls.

While investigating the physical properties and microstructures of the termite hill soils, from two locations (Dehradun, Hauz Khas), elemental composition and microstructure were investigated using different instrumentation techniques (Ganguli et al., 2013). The study infers that termite hill soil is an abundant natural source of silica; and the form of silica (α-quartz and β-cristobalite are the two forms observed) present in them varies from place to place. From the comparative study of the two samples, they concludes porosity, microstructures and elemental composition do not differ much. The inference drawn, however, is not conclusive as their investigation is based only on two termitaria soil. Conclusion based on only two termitaria (that to without ascertaining the associated termites) needs a reality crosscheck with valid sampling numbers. The research attempt is certainly a novel and worthy attempt in the termite R&D, in particular where less research attentions are diverted with la test nanotechnological inputs. However, the research article suffers some serious setbacks in drawing conclusion. Most intriguing fact is their study did not include the control soil (surrounding termite hill soil). How they could conclude that the termite hills generate nanocrystalline silica in the absence of these critical control values. While acknowledging the preliminary nature of their endeavour, we expect more meaningful outcomes from their laboratory.
Taxonomic value of termitaria – inconclusive (Kalleshwaraswamy, 2011)

Termite mounds may give only some supplementary information on taxonomic identification of concerned termites. Many species including Odontotermes obesus show a remarkable degree of intraspecific variation. The species may construct 4 or 5 different types of mounds, and is attributed to ecological adaptation. As stated (Ganguli et al., 2014), shape and size of the termite hills vary depending on the termite species. Difference in the shape and size of the mounds suggests that they were built by different species of termites. This general statement cannot be taken granted to conclude two termite hills as of different species. In fact, as per the stalwarts and world renowned termitologist, Roonwal (1977), termitaria varies significantly.

In the Indian region, the earthen mounds are reported to be built by species of genus Odontotermes: O. assmuthi, O. brunneus, O. feae (occasionally only), O. gurdaspurensis, O. microdentatus, O. obesus, O. redemanni and O. wallonensis (Roonwal, 1970), and also from the genera Macrotermes, Hypotermes, Trinervitermes and Nasutitermes (arboreal mound).

Newer dimensions

Termitaria vis-s-vis microbiology -

Termites thrive in abundance in terrestrial ecosystem, play a key role in biorecycling of lignocellulose, with the help of microbial symbiotes, this lignocellulose digestion is possible. Termite (Isoptera) order comprises a complex assemblage of diverse species, divided into two – the lower termites and higher termites (apical family: Termitidae). Lower termites with dual decomposition system, consists of termites’ own cellulose and those of its gut protists, whilst higher termites (normally make termite hills) degrade cellulose apparently by their own enzymes (in absence of symbiotic protists)(Rina et al., 2006). It is worthwhile checking whether the nanomaterials are ubiquitous in these two types of termite soil/mud tubes or not. This certainly necessitates large number of diverse termite hill soil as well as mud tubes sampling. Then only concrete conclusions can be drawn on presence and role of nano-materials like nc-Si.

Termitaria vis-à-vis thermal regulation

Nanocrystalline silica (nc-Si) has many useful advantages over amorphos-Si, one being that if grown properly it can have a higher electron mobility, due to the presence of the silicon crystallites. It also shows increased absorption in the red and infrared wavelengths, which make it an important material for use in a-Si solar cells. One of the most important advantages of nanocrystalline silicon, however, is that it has increased stability over a-Si, one of the reasons being because of its lower hydrogen concentration (http://en.wikipedia.org/wiki/Nanocrystalline_silicon). The much intrigued termitarium-soil-system, as how benefitted with nc-Si, can in detail contribute a lot in understanding their ecology in the associated context of locality.

One of the thrust areas of scientific interest of nanocrystalline materials is their thermodynamic properties. Nanomaterials in termite mound soils may be of significant fundamental interest to explore the thermodynamic consequences of this material system in the much intrigued but amazing thermal regulation capacities of termite mounds.

Termitaria are often termed as lungs of the termite colony. Nothing less than a sophisticated centrally air-conditioned building, these termite abodes
are obviously provided with such nano-materials which might be providing much needed insulation, thermal regulation in turn. The main application of nc-Si is in the field of silicon thin film solar cells, as this has about the same bandgap as crystalline silicon, which is \(~1.12\) eV, it can be combined in thin layers with a-Si, creating a layered, multi-junction cell called a tandem cell. The top cell in a-Si absorbs the visible light and leaves the infrared part of the spectrum for the bottom cell in nc-Si (http://en.wikipedia.org/wiki/Nanocrystalline_silicon). Proofs of nanoparticles (nc-Si) only strengthens such claims and the current article (Ganguli et al., 2013) is certainly a paradigm shift in the conventional research endeavours in Indian context.

We came across an article (Bansal et al., 2006) that describes fungus (Fusarium oxysporum) - mediated biotransformation of amorphous silica in rice husk to nanocrystalline silica. Fungus rapidly biotransforms the naturally occurring amorphous plant biosilica into crystalline silica and leach out silica extracellularly at room temperature in the form of 2-6 nm quasi-spherical, highly crystalline silica nanoparticles. There is possibility that the fungal symbiotes extant in termitarium-soil-system, might be contributing to the nanocrystalline silica, which implies that these nano-materials are present only in higher termites (Fam: Termitidae) but not in mound building lower termites (eg. Rhinotermitidae). It is worthy verifying the carton nests for nc-Si materials. Concerted research efforts are needed in this line.

Soil from H. indicola (a lower termite of family Rhinotermitidae) mounds and mud tunnels was also subjected to organic and microbial biomass carbon analysis, DNA extraction to verify the functional role of soil microbes and possibility of termite DNA traces. The $C_{\text{mic}}/C_{\text{org}}$ Ratio relates to the microbial activity. This ratio was found significantly lower in mound soil as compared to the nearby soil indicating the antiseptic nature thus substantial reduced soil microbial population (Mahapatro and Arunkumar, 2013). Such antiseptic nature of termite hill soil is well known fact, but the reasons are not very clear, though reports of prevalence of Streptomyces is notable (Chouvenc et al., 2013) in lower termite Coptotermes formosanus. This latest report describes a non-nutritional exosymbiosis in a termite, in the form of a defensive mutualism which has emerged from the use of faecal material in the nesting structure (carton nests, unlike soil hills in Odontotermes) of Coptotermes. However, a new alkaloid isolated from the ethyl acetate extract of the culture of a termite associated Streptomyces koyangensis BY-4 showed weak antimicrobial activities against a panel of test microbes (Shu-Feng Biac, 2013). Thus, role of nano-materials may be worth verifying in higher termites (mound forming termites like Odontotermes spp.).

In terrestrial ecosystems, the largest pool of amorphous silica (a-Si) is stored in soils and is an important reservoir of biologically active Si for the global biogeochemical cycling of Si (Loredana Saccone, 2008). How it is converted to nc-Si in termite-soil-system and its implications are certainly a relevant researchable issue in the present context of global warming and climate change. Soils modified by fauna such as termites and earthworms may acquire new properties that significantly differ from the original. Consequently, faunal modification of soils may affect their agricultural use. Researches in this line certainly will through new lights in this new dimension of agricultural science.
REFERENCES


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