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Mini Review

Nanoparticles and the Building Industry-A Short Review

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Nanoparticles have been used to protect the exteriors of built structures for many years, with $nTiO_2$ having a major role in the production of self-cleaning surfaces. Photo catalysis leads to the liberation of substances such as Reactive Oxygen Species, which can effectively remove organic contaminants, including the disfiguring microbial growths, from the surfaces. Light exposure is not essential for this activity, however some engineered nanoparticles have been shown to have inherent antimicrobial properties. Other nanometals have been employed, sometimes together with TiO_2, or with materials such as stone consolidants. A brief review of some recent research in the area, including ecological problems that can arise when the particles are released into the environment, is presented. It is essential that standard testing methods, both for nanoparticle efficacy and for ecotoxicological effects, be developed. Nanoparticles (NPs) of metal oxides have been used to protect building surfaces against microbial bio film formation for many years. NPs of TiO_2 (n-TiO_2), especially, have been used to produce surfaces that are self-cleaning on exposure to light, when photo catalytic activity destroys organic materials, including microorganisms. The antimicrobial effects are mainly due to interactions with DNA and proteins and penetration of the cell membranes Whang [1], and Reactive Oxygen Species (ROS), produced by photo catalysis, are responsible for much of the antimicrobial activity. However, engineered nanoparticles have also been reported to show non-photo catalytic antimicrobial action Ortega-Morales [2] and Loh [3] demonstrated this for n-ZnO in cement. The latter authors also suggested that ZnO, either as nano- or micro- particles, could be a better option than TiO_2 for use as an antimicrobial agent in cement-based materials, a suggestion that had previously been made for paint Lin [4] Particles are generally classified as "nano" sized if they measure less than 100nm and Folli [5] suggested that TiO_2 particles of 154±48nm should be designated "microsized" (m-TiO_2), as opposed to the "nanosized" (n-TiO_2) particles of 18±5 nm. It is important to note that commercially available nanoparticle suspensions may include micro particles Ohtani [6] Loh [3] and this may alter the homogeneity of the application, since differently sized particles will show different degrees of aggregation. The total surface area of the particles is an important functional parameter and aggregation obviously affects this nanoparticles based on Ti, Ag, Zn and Si are those produced in greatest amounts worldwide, with Si>Ti>Zn>Ag, followed by Cu Nowack [7]. This is also the order of preferred use in the building industry, although Si NPs are not employed for an antimicrobial function. Suspensions of mixed NPs or NPs mixed with other chemicals have also been tested for their efficacy against bio fouling of building envelopes. Frequently the mixtures are found to be more effective than a single NP. Substances that have been mixed with nanoparticles to improve function include biocides, heavy metals, and water repellants/stone consolidants. Examples can be found in Fonseca [8] Pinna [9] Banach [10] La Russa [11] Graziani [12] and Batista [13].

Ortega-Morales [2] have reviewed some of the literature on the use and testing of Ti, Ag, and Zn and Cu nanoparticles for protection of cultural heritage and have emphasized the importance of appropriate procedures for testing efficacy. Ag, Zn, and Cu, as well as the more commonly used Ti, NPs have been shown to be effective in control of bio film formation on built structures, either singly or in mixed formulations. However, it is difficult to compare the treatments because of the various methods employed intesting.

The use of standard test methods and organisms is greatly to be desired. After application, release of NPs may occur when the coatings are not adequately fixed to the stone or when they are not sufficiently effective to prevent stone degradation and crumbling Shandilya [14] Carmona-Quiroga [15]. Those NPs that end up in the water systems can adversely affect aquatic and marine life and in the soil essential microbial interactions may be interfered with, affecting functional diversity Minetto [16] Shen [17]. In activated sludge, denitrifying bacteria may be inhibited Chen [18]. There is limited understanding, however, of the environmental fate of released NPs. Ecotoxicological studies include effects on bacterial activity and survival, which vary according not only to dose, but also microbial species and test procedure used Eduok and Coulon [19]. Standardization of test methods is urgently needed. NP transport in the aquatic environment is affected by aggregation, dissolution, and transformation. These processes depend on size and shape of the particles, type and concentration of electrolytes, and biogeochemical and hydrodynamic conditions Peng [20] Pulido-Reyes [21]. Extracellular polymeric substances (EPS) released by aquatic microorganisms may affect the stability of NPs. Adeleye showed that the dissolution of n-CuO was increased by EPS. Because of the huge variations in environmental conditions, modeling and predicting the environmental fate and distribution of NPs is difficult and remains one of the major challenges for the future.

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