

# **Exposure to Amorphous Colloidal Silica and Associated Health Effects**

A Review of the Scientific Literature – Prepared for Lythic Solutions, Inc.

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## **Introduction**

To date, little research has been done to evaluate the safety of amorphous silica in our environment, on our health, or in the workplace. Presently, there is no substantial evidence available to disprove that the behavior of nanoscale amorphous silica, within the lungs or other organs, is not harmful to human health and development. OSHA (Occupational Safety and Health Administration) has instituted a PEL (Permissible Exposure Limit) of  $[80\text{mg}/\text{m}^3]/\% \text{SiO}_2$  for respirable amorphous silica based on a TWA (Time Weighted Average) of eight-hours per workday (4). The NIOSH (National Institute of Occupational Safety and Health) REL (Recommended Exposure Limit) for amorphous silica is  $6 \text{ mg}/\text{m}^3$  (6). Although amorphous silica has not been recognized as Immediately Dangerous to Life or Health (IDLH), NIOSH recommends the use of respiratory personal protective equipment (PPE) in work environments that exceed these exposure limits (5). These exposure limits are not completely protective against silicosis or other lung diseases, especially in hypersensitive individuals.

Many experiments that have been conducted using nanoscale silica test the use of crystalline silica rather than amorphous silica. The crystalline form of silica has been well documented as the causative agent of silicosis and other respiratory diseases (Barnes; et. al. 2008). However, the present health risks associated with amorphous

silica are not well documented or understood on a mechanistic level regarding its cytotoxicity. Furthermore, it is not understood how nanoparticles gain access into cells or how they interact with the cellular machinery at the molecular level once gaining entry into cells. Therefore, this literature review investigates the potential occupational hazards associated with exposure to nanoscale amorphous colloidal silica in solution as a concrete surface treatment.

### **Overview**

*In vitro* cell culture techniques are used to test for the cellular toxicity associated with amorphous silica. Varying concentrations of amorphous silica are seeded into human or animal cell lines and then compared to controls for levels variance or abnormalities. In a study by Chang et. al., amorphous silica nanoparticles inhibited cellular proliferation in normal fibroblasts and in the carcinomic human alveolar cell line A-549 when tested at high concentrations ( $>138\mu\text{g/ml}$ ) (Chang; et. al., 2007). This result indicates that exposure to high concentrations of amorphous silica nanoparticles may be toxic to lung cells regardless of whether the cells are normal or carcinogenic (Chang; et. al., 2007).

In the same study, an MTT (tetrazolium salt-3-(4,5-dimethyltetrazolium bromide) assay (used to test mitochondrial activity and cellular proliferation) showed that the  $\text{IC}_{20}$  (the inhibitory concentration of amorphous silica to 20% of the cells) levels were higher for tumor cells than for normal cells. The author indicated the possibility that a faster cellular doubling time is inversely related to cytotoxicity (Chang; et. al., 2007).

In an LDH (Lactate Dehydrogenase) assay, used to test damage to the cell membrane in tissue culture, results were in agreement with the results of the MTT assay. Skin and pulmonary fibroblasts were more susceptible to membrane damage during 48 hr exposure to silica nanoparticles based on the levels of detectable lactate dehydrogenase enzyme (Chang; et. al., 2007). In other words, cells of the lungs and of the skin, are likely to be affected by silica nanoparticles when they are directly exposed to inhibitory concentrations of amorphous silica. The cellular mechanism of this inhibition is not thoroughly explained or understood. There is still a paucity of information on the pulmonary effects of inhaled amorphous and colloidal forms of silica (Warheit, 1995)

In a comparative *in vivo* experiment conducted by Sayes et. al., precipitated amorphous silica particles produced transient and reversible neutrophilic lung inflammatory responses at 1 or 5mg/kg body weight at 24 hr post exposure (Sayes et. al., 2007). However, when compared against carbonyl iron, the negative control in the study, amorphous silica showed a much higher level of inflammatory response (Sayes et. al., 2007). This information suggests that silica nanoparticles are capable of inducing a cascade of immune responses within the body.

In another study, a comet assay was performed in order to test the toxicity of silica nanoparticles on DNA. Barnes et. al. concluded that the comet assay results indicated no genotoxicity at either 4µg/ml or 40µg/ml doses for any of the tested amorphous silica samples (Barnes; et. al., 2008). Further studies, testing higher concentrations of silica, are necessary in order to determine the possible deleterious

effects of nanomaterials on DNA.

Despite these findings, it is well known that silica hydrosols are stable at their point of zero charge based on the Derjaguin-Landau-Verwey-Overbeck (DLVO) Theory (Bergna, 2006). This theory is based on van Der Waals forces and electrostatics of particles in solution. Consequently, it is likely that silica has a lower biological reactivity when hydrated or suspended in neutral liquids like water. Amorphous colloidal silica is accepted as having low toxicity and is an FDA-approved food additive (Clifford et. al. 2008).

### **Conclusions**

Overall, amorphous silica is an inert substance and does not pose a high risk to human health when exposure occurs at low levels. For this reason, it seems unlikely that silica exposure during the pouring application of amorphous colloidal silica hydrosol onto concrete will pose significant harm to workers if applied in a wet state. However, if this product is pressurized, hardened, dried, cut, or aerosolized by another means, an increased risk to human health via inhalation or ingestion does exist. In these cases, NIOSH recommends that exposed workers wear respirators, certified by the Mine Safety and Health Administration or NIOSH, in order to maintain exposure limits below the PEL (9). During application in existing buildings, occupants should not be exposed to the aerosolized product at hazardous levels if appropriate engineering controls and ventilation are provided at the site.

## Works Cited

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Center for Disease Control and Prevention: NIOSH website for silica HYPERLINK  
"http://www.cdc.gov/niosh/topics/silica/" <http://www.cdc.gov/niosh/topics/silica/>

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