W.R.Grace & Co.-Conn.
Synthetic Amorphous Silica Product Stewardship Summary

I. Overview

W.R.Grace & Co.-Conn. is a global manufacturer and distributor of synthetic amorphous silica (CAS # 7631-86-9) (SAS), a form of silicon dioxide (SiO_2) that is intentionally manufactured, thereby differentiating it from naturally occurring amorphous silica, e.g. diatomaceous earth. As a manmade product SAS is nearly 100% pure amorphous silica whereas naturally occurring amorphous silica also contains crystalline forms of silica. SAS can be further divided into two forms that are characterized by their distinct manufacturing practices: wet process silica (CAS # 112945-52-5), which includes precipitated silica and silica gel, and thermal process silica (CAS # 112945-52-5), which includes pyrogenic silica.

SAS has been in global production for over sixty years and is a key component of global products. The largest production volume is for precipitated SAS products followed by pyrogenic silica and then silica gel.

SAS is used in a variety of applications and products such as:

- Filler in rubber and tires
- Anti-caking or free flow agents in powdered or liquid materials
- Adhesives
- Paints and colorants
- Health care products such as toothpaste and cosmetics
- Pharmaceuticals

Although synthetic amorphous silica and naturally occurring silica variants share the same chemical composition, they should not be confused when considering health and environmental risks. Unlike naturally occurring silica, such as the crystalline form, which has been positively correlated with an increased risk of pulmonary disease, SAS has only been associated with transient, reversible pulmonary effects in humans and animals due to its short retention time. Global regulatory agencies, using both scientific epidemiological studies and animal models, have concluded that SAS does not have a significant or lasting adverse health or environmental impact.

II. Chemical Identity - Physical and Chemical Properties

The three primary forms of synthetic amorphous silica and their physical/chemical properties are shown in the following table.

Physical and Chemical Properties of Specific SAS Forms (ECETOC, 2006)

Property (units)	Pyrogenic	Precipitated	Gel
Purity, % SiO_2 (by weight)	>99.8	>95	>95 (dry)
Color	White	White	White
Specific surface area (BET, m^2/g)	50-400	30-500	250-1,000
Loss on drying (% by weight)	<2.5	5-7	2-6
pH	3.6-4.5	5-9	3-8
Tapped (bulk) density (g/L)	30-250	30-500	500-1,000
Ignition loss (% by weight)	<2	3-14	2-15
Particle size			
Primary particle (nm)	5-50	5-100	1-10
Aggregate (µm)	0.1-1	0.1-1	1-20
Agglomerate (µm)	1-250[1]	1-250[1]	NA
Porosity			
Mean pore size (µm)	None	>0.03	0.0001-1
Pore size distribution	None	Very Wide	Narrow
Specific gravity (g/cm^3)	2.2	1.9-2.2	1.8-2.2
Structure, DBP absorption (ml/100g)	250-350	80-320	80-350

[1]Agglomerate particle size is typically 100 µm

III. Applications and uses of Synthetic Amorphous Silica

As indicated, various forms of SAS have been in commerce since the 1950s and are used in a wide range of industrial applications and products. A brief discussion of some of the primary applications is provided below. This listing is by no means exhaustive and SAS continues to be used in an expanding role in the global economy.

Precipitated silica is produced in much greater quantities than other forms of SAS. The primary use of precipitated silica is for the reinforcement of elastomer products like tires, shoe soles, and mechanical rubber goods (seals, mats, belts, etc.). One of the primary benefits of precipitated silica in tires is the improvement in wet traction without increasing wear on the tread surface. According to a study by Bergman and Roberts (2006), "…precipitated silica is currently widely used in Europe, with an increasing demand in North America and Asia, as a means to reduce fuel consumption and CO_2 emissions".

Synthetic amorphous silica is widely used as a carrier for liquids and semi-liquids or as free flow agents in powdered products (cosmetics, salts, and foods), particularly for substances that attract water molecules (hygroscopic) and caking substances, to create a better product flow. SAS also provides pastes and ointments with the desired consistency and prevents separation of the various ingredients, and thus has a number of pharmaceutical and cosmetic applications. For these applications, the absorptive capacity, ability to create flow and low dust content are important considerations for their use. The following table provides a partial description of the various industrial applications, uses and properties for SAS.

Application	Important Properties
Desiccant, adsorbent	Porosity
Paints: matting	Aggregate size
Toothpaste: cleaning, rheology control	Aggregate/agglomerate size
Rubber reinforcement	Particle size, surface area
Free-flow, anti-caking agent	Aggregate size, porosity
Heat insulation	Aggregate size, purity
Rheology control (liquid systems)	Surface chemistry
Chemical Mechanical Planarization	Aggregate size/agglomerates size, purity
Anti-caking	Particle size, surface area

IV. Wet Manufacturing Processes

Synthetic amorphous precipitated silica and silica gels are manufactured using a wet process that involves an alkali metal silicate solution (or water glass) and acids, typically sulfuric acid. The process steps involve precipitation, filtration, washing, drying, milling, and granulation, followed by packing and shipping of the product. The size of the primary particles and the amount of aggregation and agglomeration are determined by the manufacturing processes' reaction conditions, e.g. pH, temperature, concentration, and amount of agitation. Silica gels are generally manufactured under acidic conditions with primary particles in the range of 1-10 nanometers (nm) that quickly adhere to form aggregates ranging from1-20 micrometers (µm) upon drying.

Precipitated silica products are manufactured under neutral/alkaline conditions with primary particles in the range of 5-100 nm, aggregates ranging from 0.1-1 µm, and agglomerates ranging from 1-250 µm. Once formed, the agglomerate is tightly bound together and extremely difficult to break apart. This physical property prevents the formation of small (nano) particles.

After precipitation, the various silica products are filtered using different techniques (e.g. filter press, membrane filter press or belt/drum filter) depending on the product being manufactured. At this stage, the product is also washed to remove any salts. The product may then be dried either by plate, belt, rotary drum or spray dryers. The final stage of the manufacturing process is milled to get the desired particle size distribution.
The final product is a white, fluffy or powdery amorphous form of silicon dioxide with a high degree of purity (upwards of 95% SiO_2) with trace amount of other metal oxides, sulfates and/or chlorides.

V. Health Effects

Synthetic amorphous silica does not pose any significant health effects to workers or end users. Since SAS has been manufactured for over six decades and has been extensively studied by regulatory and scientific agencies. Results from both animal and human studies show that adverse health effects from exposure to SAS are minimal. The absence of adverse health effects is best summarized in the recommendations of the OECD SIDS Initial Assessment Report (OECD, 2004) that states SAS is "currently of low priority for further work" due to the low exposure potential for humans. This is further supported by the available worker exposure data that continues to show there is no evidence of health hazards to workers from the manufacture and use of SAS products.

The available literature shows that SAS has a long history of use in numerous commercial and consumer products. Consumers are likely to be exposed to SAS mainly through dermal contact or ingestion of natural and synthetic forms of silica, and less likely via inhalation. Occupational exposures, on the other hand, are more likely to include potential inhalation and dermal exposures. Importantly, the long history of manufacture and use, coupled with data regarding the size distribution of solid forms of SAS, indicate there is a low potential for adverse health effects.

VI. Environmental Effects

The effects of SAS on ecosystems, various micro-organisms, aquatic and terrestrial organisms, have been investigated. These studies indicate there is no evidence of acute toxicity to organisms in the environment caused by exposure to SAS. The only exception is the desiccant effect SAS has on insects exposed through direct contact, thereby creating a simple/elegant nontoxic physical pesticide. SAS contributes positively to many biological systems through the formation of skeletons or shells of diatoms, radiolarians and sponges, provides structural strength to plant stems, and is used by plants to form needles that are used for protection.

In 2004, OECD reviewed the environmental fate of SAS products and determined that they are stable in water and air; have no adverse biodegradability; and, are not bio-accumulative. As such, synthetic amorphous silica is a positive environmental contributor and, except as noted in the case of direct contact with insects, has no adverse environmental effects.

VII. Conclusion

Synthetic Amorphous silica is a safe product which contributes to the standard of living in a wide range of applications. SAS has suffered from mistaken identity for years due to its sharing a name and chemical formula with crystalline forms of silica. The significance of the crystalline structure cannot be overstated in that it is this structure that appears to be responsible for the adverse affects that are known as silicosis. SAS by virtue of its amorphous structure does not share the biologic hazards associated with the crystalline form of silica. In reality SAS has a remarkably safe hazard profile confirmed in human, animal, and environmental studies.

VIII. W.R. Grace Contacts

We appreciate your interest in our synthetic amorphous silica products. Please feel free to contact one of the following Grace representatives should you desire additional information or have questions.

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