

An Introduction to Composite Abrasives

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Abstract:

While it's widely accepted that abrasive blasting provides the longest coating life, increased awareness about the adverse health and environmental effects plague professionals who seek to maximize the life of protective coatings. The fugitive emissions associated with open dry abrasive blasting and the serious group of health-related agents associated with alternative abrasives, make specifying and using abrasive blasting more costly to manage and control than even before. Corporations and managers must recognize the detrimental health effects on bystanders and the long term liability they may face. For years, attempts to return the same benefits associated with conventional abrasive technologies have been attempted using alternative abrasive technologies while limiting the drawbacks, but few have succeeded. One technology, composite abrasives, over the past two decades has emerged as a viable alternative.

The Questionable Transition from Silica Sand to Conventional Alternative Abrasives

Despite the fact that “Abrasive blast cleaning is perhaps the most productive method of surface preparation for coatings that require both an anchor pattern and a high degree of surface cleanliness”¹ its use is under continued scrutiny – and has been for years. Starting in 1947 the United Kingdom banned the use of silica sand for abrasive blasting material; Germany, Sweden, Belgium and other countries soon followed.²

Numerous governmental bodies at federal and state levels in the United States have banned the use of silica in abrasive blasting as well. The U.S. Navy, Air Force, Coast Guard, and 23 state Departments of Transportation have banned silica blasting. In addition, the U.S. National Institute for Occupational Safety and Health (NIOSH) has recommended banning the use of silica in abrasive blasting since 1974.³

The public turning point though came in a 1992 NIOSH published Alert, *Request for Assistance in Preventing Silicosis and Deaths from Sandblasting*, where OSHA asked for immediate help from industry trade groups and publishers, to disseminate the report’s findings that there are... “very high silica dust levels produced during sandblasting and... workers in this occupation were at extremely high risk of developing silicosis.” The alert described “99 cases of silicosis from exposure to crystalline silica during sandblasting. Of the 99 workers reported, 14 have already died from the disease, and the remaining 85 may die eventually from silicosis or its complications.”⁴

In 1996, under Regulation 3.107.5.14 and schedule 5.2 of the *Occupational Safety and Health Regulations (OSHR)*, the Work Safe Western Australia Commission prohibited “substances that consists of or contains 2% of more dry weight of crystalline silicon dioxide [aka silica] as a contaminant” to be used as abrasive material. The list included river, beach and white sand products, as well as those derived from diatomaceous earth - and other particles from quartz rock.

Just three years later (1999) through Regulation 300(b), OSHR mandated that by 1 January 2002 “materials containing more than 1% crystalline silica for abrasive blasting is prohibited in all Victorian workplaces.” And further in the same regulation, OSHR provided their list of substitute abrasives as being garnet, crushed glass, glass bead, metal shot, steel grit, aluminium oxide, granulated plastic and certain metal slags - noting that “metal slags may contain high levels of toxic metals such as lead and chromium which may cause other health and safety, and environmental risks.”

The aforementioned country’s governmental bodies have demonstrated their concern for safety and health and have paved the way for what many have considered safer work practices. They have also demonstrated that the abrasive blasting process can be carried on effectively without the use of sand. So, as the focus continued to shift away from the use of sand, several abrasives have successfully replaced it to become accepted conventional alternatives. In fact, between 1996 and 2004, US consumption of substitute abrasives increased while the consumption of silica sand abrasives decreased 47% (from 1,470,000 metric tons to 784,000 respectively).⁵

Looking back, the industry's switch to conventional alternative abrasives could be considered hasty. A 2006-2007 Evidence Package organized by NIOSH's Respiratory Diseases Research Program (RDRP) noted "The Alert recommended the use of abrasive substitutes for sand. However, at that time the economic feasibility of substitute use and the potential toxicity of substitute abrasives were not fully understood." And on in the same package, "RDRP scientists started the evaluation of substitute materials with a literature search of data concerning the toxicity of abrasive substitutes. Significant knowledge gaps were noted." To fill in the "gaps," the evaluation of alternative abrasives proceeded through controlled test blasting. The costs, effectiveness and the airborne elemental metal concentrations of alternative abrasives generated during blasting were also measured. Among the RDRP findings, were the following results...

- "Specular hematite [aka barshot] and steel grit were less toxic than sand"
- "coal, slag and olivine were more toxic [than sand]"
- "garnet, staurolite, nickel slag, copper slag, crushed glass, and treated sand exhibited toxicity in the same range as sand"

Evaluation of Alternative Abrasives

Three key reports sponsored by NIOSH were used to summarize the above findings, which shed new light on the potential switching costs (regarding worker exposure to constituent-elements found in these substitute abrasives during abrasive blasting). The first report was a laboratory study; the second report was a field study; the third study was comprised only of the analysis.

The first NIOSH-sponsored study included collecting airborne particulate (total particulate (TP) and respirable fractions (TP-10) explained in the coming text) generated during open, dry abrasive blast cleaning. The substrate used was 4.76mm(3/16in) thick, .6m (2ft) x 6m (2ft) sheets of hot-rolled carbon steel with mill scale. Testing was conducted in a blast room fit with a dust collection system and rotating vane anemometer use to control cross draft during each trial run. A .17m³ (6ft³) gravity feed abrasive hopper was used in conjunction with a No.4 6.35mm (.25in) venturi blast nozzle, connected to an automated blast cleaner, used "to reduce the potential risk to human subjects and to reduce the variability between abrasive blast trials." Air sampling employed the use of NIOSH methods 7500 for respirable quartz and 7300 for elements. A total of 29 samples were taken in (1) the air area; (2) operator area; (3) exhaust area (or dust collector) and (3) two passive samples collecting ricochet in the operator area and (4) three samples in the operator's breathing zone but outside of the blast helmet. These samples were collected for each abrasive trial - with 998 total samples taken to measure airborne concentrations. Forty different blast cleaning abrasive materials were used to evaluate 13 generic types of abrasives. The categories were coal slag, coal slag with dust suppressant, copper slag, copper slag with dust suppressant, crushed glass, garnet, nickel slag, olivine, silica sand, silica sand with dust suppressant, specular hematite, staurolite and steel grit.

There were many detailed comparisons made in the study. The ultimate conclusion was that:

- “no single abrasive category had reduced levels of all health-related agents”
- “all substitutes (abrasives) offered advantages over silica sand with regards to respirable quartz”
- “all but two... alternative abrasives have substantially higher levels of at least two health-related agents”

The second NIOSH-sponsored study, detailed six alternative minerals which could be substituted for silica sand. The tested alternatives were coal slag, copper slag, garnet, nickel slag, staurolite and steel grit (plain silica and silica sand with a dust suppressant were also included). One goal was to measure the content of airborne emissions of each alternative abrasive generated during open blasting and measuring concentrations of eleven NIOSH-selected health-related agents – all during controlled dry abrasive blast-cleaning operations. The selected agents were arsenic, beryllium, cadmium, chromium, lead, manganese, nickel, quartz, silver, titanium and vanadium.

Testing took place on the exterior hull of a coal barge in 1.5m (5ft) x4.25m (14ft) or 6.4² (70ft²) sections. Air sampling was done in compliance with NIOSH 7500 (for respirable quartz) and NIOSH 7300 (for the elements). For each abrasive, four samples were collected: (1) the area sample, (2) the operator area sample, (3) dust collector area sample and (4) the operator’s personal sample outside of the blast helmet. Over 424 airborne dust samples were taken then analyzed.

Results as reported by the authors found the study to be “eye-opening and potentially far reaching.” There was a prevailing presence of these NIOSH concerning health-related agents in the air during each abrasive test. Out of 352 individual results 293 (eight out of ten) recorded some measurable value of each tested health-related agent. A detailed report comparing each of them with each abrasive was made, but more significant were the facts that:

- “all of the alternative abrasives have higher levels of four or more of the health-related agents, as compared to silica sand.”
- consistent with the laboratory study, “no single abrasive category had reduced levels of all eleven health-related agents”
- “all the substitutes offer advantages over silica sand with regards to respirable quartz” (refer to Figure 21)
- “all of the alternative abrasives have higher levels of four or more of the other health-related agents, as compared to silica sand”

While attention continues to be placed on (1) harmful emissions generated during silica sand blasting and (2) during the removal of (for example) lead-based coatings, these test results suggest that an added focus on protecting the blaster, surrounding workers and surrounding environments from non-silica alternative abrasives themselves is also important. The authors of the study concluded after both laboratory and field studies

“the findings of this study suggest that a much broader and holistic approach to protecting workers performing any form of abrasive blast cleaning needs to be taken.”

As documented, conventional abrasive alternatives are continuously being exposed for not only how well they match the production and capabilities of silica sand blasting, but how they can adversely affect the health of those working with or working near abrasive blasting operations. Sponsored studies like those summarized, continued regulatory tightening and appeals, the negative press combined with an enhanced public awareness during the 1990s and on, have led to even more abrasive options – one alternative being composite abrasives.

Dust-Suppressing Composite Abrasives

Composite abrasives were introduced in the early 1990s to reduce the dust and subsequent exposure to surrounding workers and sensitive equipment. The core technology, also reusable, employs the combination of abrasives (e.g. aluminium oxide) and non-toxic, non-hazardous urethane sponge material - in one particle (Figure 20).

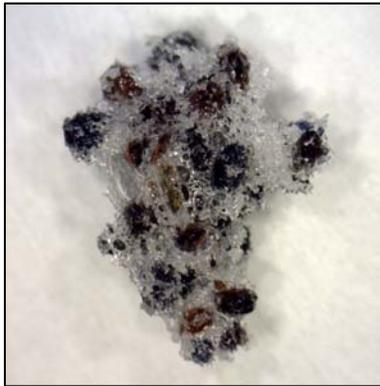


Figure 20 – Particle of composite abrasive, bonded with 30-Grit Aluminium Oxide. *Photo courtesy of Sponge-Jet, Inc.*

It has been shown to remove paint and profile just like conventional alternative abrasives and silica sand, while drastically reducing process dust and harmful ricochet (Figure 21). Many abrasive grits (bonded to sponge) are available and used to produce any number of effects including profiles (from zero to 100-plus microns [4-plus mils]).⁶ Operating requirements for composite abrasives are very similar to its conventional counterparts other than it requires a modified pressure vessel to

accommodate the flow characteristics of the sponge/abrasive particle).



**Figure 21 - Left: Environmentally sensitive project utilizing composite abrasives
Middle: Note low dust blasting with Composite abrasives
Right: Representative example of fugitive emission with mineral abrasive (garnet)**

EPA/Midwest Research Institute Measure Exposure Profiling

What makes this technology, notes the author, is its ability to suppress dust at the source – especially when compared to silica sand blasting and its conventional alternative abrasive replacements.

A series of test programs conducted by the Midwest Research Institute compared two types of particulate matter emissions generated first by coal slag and silica sand blasting (in the first series) and then (in the second series) incorporated composite abrasive blasting (with bonded 30-Grit aluminium oxide). The first test program funded by the U.S. Environmental Protection Agency (EPA) formed the basic for Section 13.2.6 “Abrasive Blasting” in the EPA’s *Compilation of Air Pollutant Emission Factors* (known as AP-42).

The first type of abrasive emission factor, total particulate (TP), are all particles regardless of size, while the second, Particulate Matter-10 (PM-10), are particles no greater than 10microns in aerodynamic diameter – or those which are more frequently respirable and absorbed by the human body. The tests programs employed “exposure profiling” which is commonly recognized by the EPA as the most appropriate method to measure airborne emissions anthropogenic particulate matter (PM). To test airborne emissions, one blaster removed paint from automobile hoods in a wind tunnel with 10mph wind speed.

A fan was mounted on one end of the tunnel while a blaster was situated on the other end. A cyclone-separator equipped with a 20x25cm (8x10in) fiber filter (operated at a flow rated 40 acfm) was placed before the fan. The fiber filter was designed to collect PM-10 particulates while the cyclone body collected all other PM emissions. After each test, the cyclone-separator was washed with distilled water. The entire wash solution was processed and passed through a Büchner-type funnel with a glass fiber filter under suction – to insure all suspended materials would reside on filter.



Figure 1 - Abrasive blasting with composite abrasives during 2nd test series. Note the absence of visible airborne emissions during blasting.
Photo courtesy of Midwest Research Institute.

Results for the first program tests (between the coal slag and silica sand and then the second program tests are shown in Table 3-2. Note that composite abrasives are commonly recycled, so the same process was incorporated into the test. Therefore, at the suggestion of one manufacturer, composite abrasives were recycled up to nine

previous uses and then 17% virgin media was added during the last recycle.

Table 3-2 – Test Results

Run	Date	Media	Area cleaned (ft ²)	Air sampling duration ^a (min)	Net concentration (µg/m ³)		Air speed ^b (mph)	IFR	Emission rate ^c (g/min)		Emission factor ^d (kg/kg media)	
					TP	PM-10			TP	PM-10	TP	PM-10
1.0.1	09.26.05	Silver 30 Virgin	13.8	39.75	1260	216	10.8	1.00	*	*	*	*
1.0.2			26.2	18.00	10200	952	10.8	1.00	9.73	0.907	0.0048	0.000447
1.0.3			16.7	18.00	6790	618	10.8	1.00	6.47	0.589	0.0037	0.000334
1.0.4			18.2	24.25	7460	404	10.8	0.99	7.11	0.385	0.0064	0.000346
1.3.1	09.27.05	Silver 30 4th Use	11.2	9.75	28200	3060	10.8	0.98	26.9	2.92	0.0254	0.00275
1.3.2			11.8	10.25	25200	2320	10.8	0.98	24	2.21	0.0155	0.00143
1.3.3			11.8	6.00	23100	3020	10.8	0.98	22.1	2.88	0.0083	0.00109
1.9.1	09.28.05	Silver 30 10th Use	6.5	17.00	22300	2820	10.8	0.93	21.2	2.68	0.0157	0.00198
1.9.2			2.7	8.25	24100	1530	10.8	0.94	23	1.46	0.0239	0.00152
1.9.3			4.1	9.50	23400	2110	10.8	0.95	22.3	2.01	0.0167	0.0015
1.9.X		Silver 30 10th Use MIX ^f	3.1	14.75	6180	809	10.8	0.95	5.89	0.771	0.0078	0.00102
2.0.1		Silver 16 Virgin	8.8	25.00	1610	196	10.8	0.95	1.53	0.187	0.0008	0.000092
2.0.2			7.3	14.00	4040	494	10.8	0.96	3.85	0.471	0.0016	0.000198
3.0.1		Coal Slag	3.2	6.00	62700	5840	10.8	0.96	*	*	*	*
3.0.2			8.2	7.50	385000	59700	10.8	0.96	367	56.9	0.0901	0.0138
4.0.1		Silica Sand 50 grit	7.5	6.25	397000	84700	7.0 ^b	1.42	245	52.3	0.125	0.0267
4.0.2			4.2	6.50	402000	76200	7.0 ^b	1.44	248	47.1	0.176	0.0333
4.0.3			3.3	7.00	487000	111000	7.0 ^b	1.42	301	68.5	0.125	0.0288

^a Times recorded to the nearest 15 s (0.25 min).
^b Tunnel air speeds were measured prior to the start of the test program. Makeup airflow changed for the silica sand tests to avoid recirculation of emissions through the facility.
^c Emissions based on "clock" time (i.e., the air sampling duration) to facilitate comparison with results from Reference [3].
^d The amount of media used is based on 7 lb/min for Sponge-Jet products and 13.5 lb/min for other abrasive media. Blast times are given in Table 3-1.
^e These tests served as "shakedown" tests. During the first Sponge-Jet media test, problems were encountered with the flow in the blasting system. The system was switched out for a new unit. Because of the long test duration, the emission rate was substantially lower than the other results. Results from that shakedown test are not included in the summary statistics. Similarly, the first test of coal slag also encountered problems with material flow and has been excluded from the summary statistics.
^f The media evaluated in this test consisted of 83% Silver 30 recycled after nine previous uses mixed with 17% of virgin Silver 30.

Tables 3-3 below displays the percent reduction recorded in average emission factors for composite abrasive as compared to coal slag and silica sand. Note the reduction in average emission factors for Silver 30 10th Use/Mix [aka composite abrasives] as compared to that of coal slag and virgin silica sand reduces TP emissions by 91% and 94% and PM-10 emissions by 93% and 96% respectively.

Table 3-3 – Percent Reduction in Average Emission Factors for Sponge Media

Condition	Percent reduction based on coal slag		Percent reduction based on silica sand	
	TP	PM-10	TP	PM-10
Virgin	94	97	96	99
10 th Use/Mix	91	93	94	96

Tables 3-5 below displays the percent reduction recorded in average emission rates for composite abrasive as compared coal slag and silica sand. Note the reduction in average emission rates for Silver 30 10th Use/Mix as compared to that of coal slag and virgin silica sand reduces TP emissions both by 98% and PM-10 emissions by 99% and 98% respectively.

Table 3-5 – Percent Reduction in Average Emission Rates for Sponge Media

Condition	Percent reduction based on coal slag		Percent reduction based on silica sand	
	TP	PM-10	TP	PM-10
Virgin	98	99	97	99
10 th Use/Mix	98	99	98	99

In addition to the material differences in emission rates/factors displayed in the above figures, the test administrator summarized that “emissions for Sponge Media [composite abrasives] are one to two orders of magnitude lower than that for commonly used abrasive materials.” This author also found the test administrator’s analogy when characterizing composite abrasive’s dust-suppressing ability by stating “when used as recommended (i.e., recycled with fresh material added) Sponge Media provides a control level essentially identical to the 95% value commonly assigned to fabric filtration.”

Questionable Replacement Abrasives

While the transition from silica sand has been completed in some countries and nearly so in others, it’s the transition to alternative abrasives technologies that remains questionable. Evidence has shown that most conventional abrasives have equal to or more toxicity than silica sand. NIOSH, as early as 1998, published their concern for certain “health-related agents” in certain mainstream alternative abrasives. Just five years ago OSHA Guidance document titled “Abrasive Blasting Hazards in Shipyards” published personal exposure limits (PELs) for all twelve health-related agents, with proven harmful effects.⁷

Test data and evidence suggests that conventional abrasives utilized for open abrasive blasting have significant health risks. These risks apply to more than just abrasive blasters. The true risk is to those near or outside the work zone including: office personnel, children in nearby schools and of course all unprotected workers.

Given the risks and costs associated with long term liability, specifications should adopt all reasonable engineering controls which can dramatically reduce toxic exposure to those nearby. These Engineering controls could include (1) full containment with filtered ventilation, (2) the use of Composite (Sponge) Abrasives or (3) other engineering controls to reduce toxic exposure levels via fugitive emissions.

AUTHOR’S NOTE:

While the author is not suggesting that silica sand should continue to be used for abrasive blasting, it is suggesting that the common alternatives can be, as documented tests suggest, just as toxic as silica sand – when considering the mineral components found to make up each abrasive alternative and the amount of fugitive emissions generated during blasting.

¹ Army Core of Engineers New Construction and Maintenance Manual Jan/99“Chapter

² (National Institute for Occupational Safety and Health 1997)

³ (National Institute for Occupational Safety and Health 1974)

⁴ CDC/NIOSH ALERT: “Request for Assistance in Preventing Silicosis and Deaths from Sandblasting”, Publication No. 92-102, August 1992.

⁵ Bolen, Wallace P, U.S. Geological Survey Minerals Yearbook - Silica, 1996 and Dolley, Thomas, U.S. Geological Survey Minerals Yearbook - Silica, 2004

⁶ Sponge-Jet, Inc. Product Datasheet “Sponge Media for Profiling and Abrading”,
http://www.spongejet.com/document_library/2_Product%20Information/Sponge%20Media%20for%20Profiling%20&%20Abrading.pdf

⁷ U.S. Department of Labor; OSHA Directorate of Standards and Guidance - Office of Maritime, OSHA
Guidance Document “Abrasive Blasting Hazards in Shipyard Employment” December 2006
http://www.osha.gov/dts/maritime/standards/guidance/shipyard_guidance.html