THE COMPARATIVE ANALYSIS OF BIOLOGICAL GROWTH AND COMMON CLEANERS BASED ON ORGANISM IDENTIFICATION AND BIOLOGICAL MECHANISMS

For the design of treatment plans for biological growths with select available cleaners.

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by

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Abstract

Biological growth on stone monuments and buildings is a common concern in architectural conservation. It is usually removed through the use of commercial biological growth cleaners. There are a number of these products on the market whose efficacy can vary by growth type and substrate. With years of experience a conservator may develop a sense of what products work best based on the type of biological growth present. However, most of this knowledge is based on trial-and-error in the field.

This thesis takes a more systematic approach to cleaning biological growth. Popular commercial products owe their efficacy to the susceptibility of different biological organisms to the active ingredients present in the cleaner. Different types of organisms have different reactions and immunities to certain chemicals, or are affected to different degrees by the cleaners and application methods. Therefore, not all cleaners are equally effective on all types of biological growth. Past studies on the subject of biodeterioration have taken two approaches: looking at the DNA identification growth found on stone, and testing the responses of different forms of biological growth to commercially available biocides. These commercially available biocides are not the same as commercially available cleaners that work through biocidal mechanisms, with cleaners generally having lower toxicity and are subject to less strict government regulation.

This paper compares and analyzes the alterations caused by each chemical agent on specific forms of biological growth. This was accomplished through the collection and propagation of samples of biological growth and laboratory testing. Several forms of biological growth, including algae, lichen, and moss were first visually identified using state and local databases with information such as cellular structure, growth type, and geographic location.
Algae samples were grown in petri dishes and tested along with larger samples of lichen and moss in the laboratory. The samples were monitored before, during, and after treatment. The effects of the cleaners were analyzed and compared to understand any differences between the reactions of cleaners and growths, and to what each growth was most and least vulnerable.

The long-term potential for regrowth was also considered through the re-examination of sites cleaned for a prior thesis in 2011. Three sites cleaned with several of the cleaners included in this thesis were examined three years after cleaning to evaluate the long-term effects of the cleaners.

The results from this study can assist in the design of custom biological growth treatment plans based on the taxonomic classification of biological growth and the substrate on which it grows.
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Introduction

Stone has been a leading building material for thousands of years. The decay of culturally significant monuments results in the loss of history and heritage. The deterioration of stone is driven by many factors, including innate properties such as porosity and mineral content, and the location and environment of the finished stone. The variables that influence the physical and chemical deterioration processes on stone also play a role in biodeterioration, the changes influenced by the “vital activities of organisms,” including their colonization, growth, reproduction, and death.¹ The presence of biological growth influences both aesthetics and deterioration.

The appearance of a structure or monument covered in biological growth offers a different aesthetic than a clean structure. In a bustling town or city a building may be cleaned because it can serve as the physical representation of a business, just as large, powerful corporations want their names on massive, inspiring buildings. However, in a cemetery the presence of biological growth provides an indicator of age, and the passing of time. Cleaning campaigns in each of these settings would be driven by different values and principles, which must be taken into account when the question of cleaning arises.

Many products are available for the cleaning and the removal of biological growth, and with years of experience a conservator may develop a sense of what products work best based on the type of biological growth present. This is because organisms have different reactions and immunities to certain chemicals.

Studies on the subject of biodeterioration have stressed the requirement of taxonomical identification due to the different contributions organisms can have on degradation processes of

A number of studies have used DNA identification of biological growth found on stone to analyze their colonization patterns and aid in determining contributing factors of deterioration from bacteria to trees and shrubs. Some studies have used information on growth identification to analyze and compare the responses of different identified forms of biological growth to commercially available biocides. These biocides are chemical products subject to government regulation due to the toxicity of their active ingredients. A 2010 Italian study found correlations between the efficacy of an Italian biocide, Biotin N, and distinctly different types of biological growth, particularly cyanobacteria, green algae, and black fungi.¹

While there are a number of studies examining the efficacy of government-regulated biocides on different types of biological growth, there is a lack of research into the same selective nature of other common and commercial products that are marketed as biological growth cleaners, a class of products separate and distinct from government-regulated biocides. These biological growth cleaners have harmful effects on biological organisms and aid in their removal, but are not considered biocides. This thesis attempts to combine the identification of biological growth on stone with the effect these commercial cleaners have on different forms of growth. The combination of these two methodologies, organism identification and testing, aided in identifying products at the disposal of a conservator that are best-suited for the chemical removal of biological growths. This process included the visual identification of biological growth using free, state and national plant databases as an alternative to DNA identification, which is expensive and time-consuming. The goal of this study is to create a methodology to

help identify chemical vulnerabilities in certain organisms in order to design treatment plans to best effectively and efficiently remove biological growth. This was accomplished by subjecting known samples of biological growth to known chemical agents and analyzing the alterations caused by each chemical agent in the laboratory.

The long-term potential for regrowth was also considered through the re-examination of sites cleaned in a prior thesis in 2011. Three sites cleaned with several of the cleaners included in this thesis were examined three years after cleaning to determine how long-lasting a cleaning campaign can be. Both the initial degree of colonization and the local environment were considered in analyzing how well each cleaner has performed in the long-term.
Chapter 1. Biological Growth

Introduction

Many different organisms, from bacteria to trees, find buildings and monuments to be habitable spaces for growth. The susceptibility of a stone or masonry surface to biological growth, the accumulation of organisms such as bacteria, algae, moss, and even trees—is dependent on many factors, such as porosity, orientation, availability of nutrients and light, and the local environment. When these factors are “just right” they support the growth of microorganisms, which in turn, can support non-vascular, and higher, vascular plants (those that can retain and circulate water and have organ-like cellular organization).

The smallest and most wide-spread type of biological growth that grow masonry is bacteria, most of which are photosynthetic members of Cyanobacteria, Chlorophyta, or Bacillariophyta. Larger, non-vascular biological growths include algae, lichen, and moss. Vascular growths include grasses, shrubs, and trees. This is by no means a complete list of the types of biological growth that affect masonry and stone, but these are the most common.

In issues of conservation, identification of communities of organisms growing on stone can greatly inform a treatment program and is key in the development of long-term cleaning and monitoring programs. This process of identification uses the Linnaean taxonomic system invented in a standardized form for biology with Carl Linnaeus’s Systema Naturae in 1735.5

In biology, all living organisms are grouped together on the basis of shared characteristics with names given to these groups. This branch of the field of biology is known as taxonomy. Since its development by Linnaeus in his mid-eighteenth century works including *Systema Naturae* and *Species Plantarum*, the system has been revised and expanded. His two original Kingdoms of Vegetabilia and Animalia have most recently been classified as three separate Domain classifications, Archaea, Bacteria, and Eukaryota. The development of the three-Domain system in the field of taxonomic biology is relatively recent, when molecular techniques such as DNA sequencing brought to light conflicts between the pre-existing five-Kingdom classifications of Monera, Protista, Plantae, Fungi, and Animalia. The Domain system, based on evolutionary relationships which are evaluated at a genetic level, has resulted in another professional field of biological classification, called phylogeny. The studies into the evolutionary history of taxonomic groups lead to a clearer picture of how life evolved and continues to evolve, and these discoveries occasionally require a reconsideration of how named organisms are classified.

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Figure 1.2 Hierarchy of biological classification.\(^7\)

Figure 1.3 An example of the process of classification for the moss rose.\(^8\) The process begins by its classification as a plant, in the Plantae Kingdom.

\(^7\) Image courtesy of Peter Halasz, Wikimedia Commons.
\(^8\) Cain, *Discover Biology*, 215.
There are seven ranks, or taxa, under which organisms are classified based on their similar and divergent characteristics based on physiology and genetics (Figure 1.3). Each organism receives a two-part name, with the first part indicating the genus name the organism belongs, and the second part indicating the species such as *Canis lupus*, the binomial name for the grey wolf. While these classifications were traditionally based on physical and behavioral characteristics, DNA sequencing has played an increasing role in linking organisms through their evolution from a common ancestor and in categorizing species.

Biological growth on masonry is identified in several ways depending on the requirements of the situation. Oftentimes in the field, simple visual identifications such as noting moss, lichen, and algae, are the major method of identification. This broad classification does not work on microorganisms such as bacteria and algae, whose appearance can be similar to other biofilms. A more specific scientific identification can be carried out at the genetic level using molecular techniques such as polymerase chain reaction (PCR) techniques. However, PCR is not a field technique and requires expensive, specialized materials and techniques. This level of identification is not usually feasible for the analysis of biological growth in historic preservation except on a well-funded research project. This thesis shows that this level of organism identification is not necessary for a beneficial effect on conservation efforts, and that identification at the Family or Genus level is sufficient.

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10 Biofilms are aggregate of microorganisms in which cells are frequently embedded with a self-produced matrix of extracellular polymeric substance (EPS) adhere to each other and/or a surface. The EPS is generally composed of extracellular DNA, proteins, and polysaccharides.
11 PCR is technique in molecular biology that is used to amplify a DNA target by making thousands of copies. It relies on repeated cycles of heating and cooling for the separating of DNA strands and enzymatic replication of DNA. A sample of DNA containing the target sequence is combined with a DNA polymerase, an enzyme responsible for piecing together nucleotides into a strand of DNA using one strand as a template, and a DNA primer, which contains the complementary DNA sequence to the target DNA sequence, and serves as the attachment site for the DNA polymerase.
Common forms of biological growths affecting masonry

Algae, cyanobacteria, lichen, fungi, mosses, and higher plants each affect masonry and stone through varying mechanisms. Due to the more common presence of algae, cyanobacteria, lichen, and mosses, they have been examined more in-depth in this thesis. The presence of fungi on stone and masonry is limited due to the nutritional requirements of a fungus. They are chemoorganotrophic organisms that consume organic molecules\(^{12}\) for energy production and growth. These organic molecules include lipids and sugars that photosynthetic organisms can make by turning inorganic sources of carbon such as carbon dioxide into organic carbon. These molecules need to be abundantly present to support the growth of fungi, which is why fungi are more commonly found on decaying organic matter such as dead trees and forest floors. While fungal staining occurs on masonry, it is far less common than the previously mentioned phenomena due to the lack of consistent nutrient sources that would support fungal organisms. Higher plants were not examined because their most effective methods of removal rely on mechanical removal, a factor that has been removed in the methodology of this thesis to better understand the chemical action of available cleaning products.

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\(^{12}\) Organic carbon molecules are often differentiated from inorganic carbon molecules based on the presence of hydrogen and the absence of metallic elements. Organic carbon molecules are soluble in organic solvents, such as hexane and acetone. Inorganic carbon molecules are not, and are soluble in inorganic solvents such as water, acids, or bases. This is the basis of the phrase “like dissolves like” and the reason oil and water do not mix.
Algae and cyanobacteria are photoautotrophic organisms that rely on sunlight and carbon dioxide to form complex organic molecules used for growth. They are unicellular organisms where one cell is responsible for all vital functions, including growth and reproduction. Small species of algae reproduce asexually through cell division, while larger species reproduce through the production and dispersal of spores. Most species of algae only grow in aquatic environments, where water is more available than on damp stone surfaces. However, the most common form of algae capable of colonizing stone surfaces are members of

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13 A photoautotrophic organism uses light as their primary energy source, usually through the reduction of carbon dioxide and photosynthesis. This allows them to make complex organic compounds to create and store energy. Because of this ability to form complex molecules which are relied on by other types of organisms for growth, photoautotrophs are considered primary producers.
the division Chlorophyta, known as green algae, with thirty five species identified in studies of biodeterioration on stone.  

The appearance of algae and cyanobacteria on stone may be similar, but they are very different organisms on the cellular level. Algae are eukaryotic organisms that have dedicated cellular structures for certain functions including a nucleus where genetic material is stored; whereas cyanobacteria, as members of the Kingdom Bacteria are prokaryotic and do not have a defined cellular structure for their genetic material. There is more organization on the cellular level in algae, where processes such as photosynthesis occur in specialized organelles within the cell. In prokaryotes such as cyanobacteria there is no such organization, with all cellular processes taking place within the cytoplasm.

Algae and cyanobacteria usually appear as green and blue-green stains on stone surfaces, but are also attributed to red and black staining. Green and blue green algae of the divisions Chlorophyta and Cyanophyta are the most common algal growths found on stone. Other less common species include Bacillariophyta and Rhodophyta. Bacillariophyta, the major division of phytoplankton, are also known as diatoms and are found on permanently wet stonework and are yellow-brown in color. Rhodophyta, also known as red algae, requires a higher level of environmental humidity than the previously mentioned genera and are rare on stone works outside an aquatic or fountain-like environment.

Blue-green algae growing on stone are actually biofilms of cyanobacteria of the division Cyanophyta. The bacterial cells are contained in a gelatinous mixture known as the sheath, which allows the cells to adhere to the substrate. This sheath also slowly absorbs and releases water,

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14 Caneva et al., Plant Biology for Cultural Heritage. 72.
16 Caneva et al., Plant Biology for Cultural Heritage, 73.
17 Ibid, 73.
providing enough for the cell colony to grow and survive when water may not otherwise be available. The biofilms created and maintained by cyanobacteria are the major form of attachment to their substrate, and consist of negatively charged polysaccharides, and can contribute to the deterioration of the substrate through complex-forming and leaching processes that attack mineral constituents of the stone surface such as calcium carbonate and silica (Table 2.1). These films also serve as a source of organic material for heterotrophic organisms such as fungi.

More than forty genera of cyanobacteria that have been identified in studies on biodeterioration. As photoautotrophic organisms, their primary growth requirement is light, whose energy is used to convert carbon dioxide into organic carbon molecules. Heterotrophic organisms are not capable of such processes and organic carbon is an environmental requirement for growth. This means algae and cyanobacteria are one of the first growths to colonize stone surfaces, and aid in the creation of an environment suitable for further organism colonization, such as those species that utilize byproducts of fossil fuel consumption like sulfur oxides and fly ash and other pollution products that are deposited on surfaces by wind and rain.

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18 Caneva et al., Plant Biology for Cultural Heritage, 71.
19 A heterotrophic organism is one that relies on the organic molecules produced by autotrophs for growth.
21 Caneva et al., Plant Biology for Cultural Heritage, 71.
22 This process is also referred to as the fixing of inorganic carbon.
Figure 1.5 Lichen growing on granite stairs at Woodlawn Cemetery. Photo by author.

Lichens are small plant-like organisms that readily colonize stone. Their appearance varies greatly, with different textures and shapes between lichen species, but they often sit close to the surface. They can be waxy or heavily textured like moss, but they grow closer to their substrate than mosses, and have distinct shapes unlike algal films. Some lichens are large and round with varying shades of green. Others can be much smaller and grow in groups. While their colors vary from light to dark green, shades of yellow, and even reds and brown, their color is due to the presence of chlorophyll, the same substance that makes algae and most tree leaves green. Some chlorophylls have structures that result in colors other than green, such as those in red algae and Japanese Maple trees, but they are much more rare.

Lichens are a “symbiotic partnership” of a fungus and a photosynthetic organism such as algae or cyanobacteria.\footnote{U.S. Forest Service, Rangeland Management Botany Program. “Lichens,” accessed March 23, 2013. \url{http://www.fs.fed.us/wildflowers/interesting/lichens/index.shtml}.} Some researchers have described lichen as “small, self-sufficient
ecosystems, formed by a fungus (mycobiont) that depends nutritionally on primary producers (photobionts)." It is rare for a lichen to contain a photobiont (algae) that cannot grow independent of its mycobiont (fungus) partner. Fungi are one of the six separate kingdoms in biological taxonomy. Unlike plants, which get energy through photosynthesis, fungi are heterotrophic and must rely on other organisms for their energy. In lichen, the fungus gets its energy from its chlorophyll-containing, photosynthesizing partner. This partner can be certain species of green algae and blue-green cyanobacteria. Most species of lichen consist of one of twenty five genera of green algae, while less than 10% of lichen consist of one of fifteen genera of cyanobacteria. Even fewer, around 3-4% exist with both cyanobacteria and green algae in symbiosis.

Some lichen reproduce asexually through the production of diaspores--spores that contain both the seed needed for new plant production, and additional tissues necessary for the growth process. Others reproduce sexually where fungal spores must find a compatible algal partner spore upon release.

While lichens are multicellular organisms, there is no organization of cells into tissues or organs in the thallus (body), such as roots, leaves, and stems in vascular plants. The forms of growth of thalli may be:

- crust-like (crustose): the thallus penetrates the surface and adheres close to it, forming a crust ("a" in Figure 1.6 below). This type is found in more than 50% of lichens.
- foliose: the thallus penetrates the surface with its thread-like rhizines, and is easily

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25 Ibid, 78.
26 Ibid, 78.
27 Ibid. 78.
28 Rhizines are root-like filaments that are attached to the hyphae. They are like roots found in vascular plants, except that they lack cellular organization like true root systems.
removed (“b” in Figure 1.6 below).

- fruticose: the thallus grows in three dimensions, generally anchoring itself to the surface with a button-like rhizine (“c” in Figure 1.6 below). Foliose and fruticose thalli make up 45% of lichens.

- endolithic: the thallus grows deeply into the substrate, emerging only when the thallus reproduces and releases its spores (“d” in Figure 1.6 below). These types of thalli only grow predominantly on calcareous stone.

![Figure 1.6](image)

**Figure 1.6** Different forms of lichen growth on stone: (a) crustose lichen; (b) foliose lichen; (c) fruticose lichen; (d) endolithic lichen.

Most lichen thalli have three distinct internal layers, including the cortex, the photobiont layer, and the medulla. The cortex controls the absorption of water, serves as a physical barrier from other microorganisms and the environment, and contains some pigments such as melanin to protect from UV exposure. Cells of the photobiont sit right below the cortex for optimal light absorption. The medulla is a loose system of hyphae and intercellular spaces that connects to...

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31 Hyphae are long, filament-like structures of fungi that are the major method through which lichen attach to their substrates.
he rhizines, which attach the lichen to their substrate. They are capable of penetrating the surface from three tenths of a millimeter, to sixteen millimeters.\textsuperscript{32}

\textit{Bryophytes}

![Figure 1.7 Moss and lichen growing on a tree at Woodlawn Cemetery.](image)

Bryophyta was once the common name for non-vascular land plants, including mosses, liverworts, and hornworts. Mosses are the hardiest of the group, more capable of withstanding temporary dry conditions. Liverworts can grow on stone, but because of their moisture requirements, are often found in boggy soil and along the edges of bodies of water. Hornworts are the least hardy, preferring tropical climates with ready-present humidity, and are not generally found on stone. Mosses, and to a lesser extent, liverworts, are found on stone and have been found to participate in material deterioration.\textsuperscript{33} However, recent genetic research revealed that mosses, liverworts, and hornworts do not share a single phylogenetic lineage and while they share similar characteristics in appearance and reproduction, it is not the result of a close shared


\textsuperscript{33} Ibid, 12.
ancestry. In taxonomy, the term Bryophyta now applies exclusively to mosses, with liverworts and hornworts each in a separate phylum, Marchantiophyta and Anthocerotophyta, respectively.

Bryophytes are small, soft plants that grow in clumps or mats in damp, shady locations. They can be as small as a few centimeters in height, to as large as 20 centimeters in height depending on the species. They do not flower, and reproduce through the generation of spores that are carried by animals, small insects, and the wind.

The order of Byrospida is the largest classification of mosses, containing over 95% of all moss species. These are also called “true mosses,” because of their lack of a multicellular root system, using small hairs called rhizoids to attach themselves to a substrate. These rhizoids are much like the rhizoids used by lichen to attach to surfaces, and they serve the additional purpose of absorbing water and mineral salts from the environment. However, their capacity to absorb and control moisture loss through rhizoids are significantly reduced from higher plants. Like algae, cyanobacteria, and lichen, mosses lack the tissue differentiation to store water and rely on a constant supply in their environment. They also have weaker cell walls that do not minimize water loss.

Because true mosses lack a strong system of attachment, they often grow on rougher surfaces such as stone in the wake of other organisms, especially lichen. The uneven surface texture is ideal for the attachment of the small hairy rhizoid of mosses.


Vascular plants are eukaryotic organisms that contain distinct tissues where separate vital functions take place. These tissues are organized into organs, such as roots, leaves, and stems. The roots of vascular plants have the most impact on its substrate, requiring significant depth of penetration, from inches to feet depending on the size and age of the plant.

There are two separate classifications of vascular plants, depending on their method of reproduction. Pteridophytes, which reproduce with spores, are only found in areas with sufficient humidity, such as wet tropical climates and humid continental climates. Spermatophytes, which reproduce with seeds, include both seed-bearing and flowering plants.

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Conclusion

The plants that grow on stone and masonry have specific anatomical, ecological, and physical characteristics that allow them to survive in an organic nutrient-limited and inhospitable environment. There is a linear progression in the colonization of monuments by biological forms. Small organisms precede larger ones, and create environments conducive to further colonization.

Algae, cyanobacteria, lichens, and mosses are the most common forms of biological growth on stone and masonry surfaces. Higher plants such as shrubs, vines, and trees are found on stone and masonry structures, however they are secondary colonizers, often following non-vascular growth. The first forms of biological growth to inhabit stone are those that gather and rely on atmospheric pollution byproducts, in moisture-rich environments. Through their buildup, these forms increase the substrate surface area by altering mineral grains physically and chemically, and small, less demanding plants are able to take root. They are then followed by larger, rooted plants. This does not occur overnight, and the key period in this succession is before secondary colonization takes place. The removal of primarily colonizing forms of biological growth can be considered preventative maintenance, but in order for such a program to be viable, it must be effective, easy to apply and monitor, and gentle on both operators and the substrate. After understanding the types of biological growth present, the next step is to understand the threats that theses growths present and their methods of substrate deterioration.
Chapter 2: Biodeterioration & Mechanisms

Introduction

Biodeterioration was first defined in 1965 by the conservation scientist H.J. Hueck as “any undesirable change in the properties of a material caused by the vital activities of organisms.” Biodeterioration is the result of deterioration processes linked to the presence of biological growth, from aesthetic alterations, to the irreversible transformation or breakdown of the substrate. Mechanisms of biodeterioration can result in disaggregation, dissolution, loss of mineral cohesion, and discoloration. Biological and environmental sciences the process of biodeterioration is also called biodegradation, however the term biodeterioration is commonly used in the context of cultural heritage conservation and preservation.

Many forms of biological growth that participate in the deterioration of stone are discussed in the previous chapter. This thesis focuses on the more common forms of biological growth in architectural conservation: algae, lichen, and moss. A number of scholarly studies on these forms of growth and their interactions with various stone substrates have been performed. The results of a few of these studies and their influence will be discussed in this chapter. There are two distinct scholarly groups of thought in the removal of biological growth: those who believe that in most cases, it is best to remove biological growth before it proceeds to a point where it can cause mechanical damage; and those who believe that biological growth has a protective effect on stone and should not be removed.

40 Ibid, 15.
Past Research in Biological Growth and Biodeterioration

Plants are never indifferent to their substrate. They alter stone surfaces through an intricate relationship and complex reactions between itself and its substrate. The beginning of this alteration process is difficult, if not impossible to pinpoint. Organisms that colonize stone surfaces are parts of lithobiotic communities—groups of organisms that inhabit stone and may use the inorganic minerals as nutrients for growth. These communities of organisms directly participate in decay processes of stone, causing aesthetic, structural, and chemical damage, in addition to supporting additional biological growth.

The processes involved in the biodeterioration of stone have been a major source of research since the 1980s. Early studies worked to identify the types of biological growth on various types of substrate, to analyze their role in the deterioration of elements of cultural heritage, and to shed misconceptions about the innocuousness of biological organisms.

In 1989, a conference on the Biodeterioration of Cultural Property was held in India, where international research was presented on the biodeterioration of artifacts relating to cultural heritage, including paper, textiles, and stone. Several papers at this conference presented on lichen, with emphasis on their presence at sites in Italy and in India. Seaward [et al.] noted increases in lichen attack in areas subject to man-made environmental changes, such as at archaeological sites. They also noted that structures of mixed materials showed similarly mixed...

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41 Lithobiotic organisms are those that inhabit stone.


lichen flora populations. They identified a species of lichen located at sites across Italy that appeared to be “extending its ecological range throughout Europe” affecting churches, monuments, frescos, and mosaics. The article concluded that research to this point on lichen has been insufficient and called for future studies identifying “which species [of lichen] are disfiguring but intrinsically harmless, and which cause actual physical damage.” The authors of this article proposed that there are species which may act as a protective barrier, but they had yet to be identified. This research trend continued through the following decade with many publications calling for additional research into these protective lichen species, and the search is still ongoing.

In 1991 Griffin [et al.] reviewed the published literature at the time on the biodeterioration of stone with an emphasis on historic monuments. The article’s case studies looked predominantly at Italian sites, and noted that research trends considered the surface changes resulting from biological growth, but did not go as far as identifying the attributing physical or chemical damage to biological growth. The review of biological growth considered bacteria, fungi, lichen, and mosses and higher plants, and briefly discussed their deterioration mechanisms, which are consistent with those discussed at the 1989 Biodeterioration of Cultural Property Conference. However, this team of authors believed that to leave biological growth on stone because of perceived benefits was a “misunderstanding of the nature of biodeterioration and its synergistic effect on other degradative processes.” They concluded that while it was difficult to separate deterioration stemming from a biological source from other environmental factors, biological organisms were often overlooked as sources of physical damage. They also

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46 Ibid, 203.
48 Ibid, 194.
concluded that knowledge of the species of biological growth present both helped to inform treatment options and contributed additional understanding of the damage potential if certain forms were left untreated or improperly treated. This trend in research begins to take hold in the years after this article.

The term bioreceptivity was first defined in 1995 for describing the relationship between buildings and the larger environment.49 Bioreceptivity is useful in explaining the colonization process of building materials based on innate stone factors and environmental factors. Guillitte proposes that further research be done to quantitatively define bioreceptivity for various materials, to aid in historic building restorations and choosing replacement materials.50 The article proposed future research into standardizing tests to describe the bioreceptivity of building materials and developing a sharable database of results.51 This concept was elaborated on in a 2012 article by Miller [et al.] who proposed a standardized laboratory testing protocol for the evaluation of stone bioreceptivity and the formation of a database for further research to utilize and build on.52

In 1998 Ascaso [et al.] studied the biodeterioration mechanisms at a Roman cathedral site in Spain heavily colonized by lichen, and concluded that the effects of lichen on stone were not independent of the lithobiotic community within which lichen participated.53 This was an early study that took a deeper look at the effects of algae and cyanobacteria, in addition to lichen. They found that where lichen thalli penetrated the substrate, types of damage found were those also

51 Ibid, 220.
attributed to algae and cyanobacteria, such as chlorite sheet\textsuperscript{54} separation in clays and impurities found in calcareous stone.\textsuperscript{55} These algae and cyanobacteria were able to survive while in contact with the mycobiont while not being a symbiotic partner. This study confirmed a hierarchy of damage potential in microorganisms, with fungi having higher altering capability than bacteria or algae, and also confirmed that lichen were capable of adapting to their environment. In the absence of primary producers such as algae and bacteria, there was still a loss of calcium in nearby minerals.\textsuperscript{56} The authors theorized that this was due to the high carbonic acid content, produced by the lichen in order to obtain calcium to strengthen the cell walls of the thallus.\textsuperscript{57} This result provided data against the protective role of lichen on stone, and showed that the stone penetrating thallus was capable of causing more unseen damage than earlier believed.

With an additional decade of research to build on, in 2000 Warscheid [et al.] reviewed the accumulation of literature on the biodeterioration of stone, with an emphasis on its relevance in stone conservation.\textsuperscript{58} The authors of this study compared the properties of different stone types that allow microbial communities to thrive, and defined the types of organisms growing on sandstones and marbles of a German cathedral. They elaborated on the concept of bioreceptivity, the properties of stone that increase or decrease its susceptibility to biological weathering, which was defined in an earlier ecology 1995 study by Guillitte. Warscheid’s work took an in-depth look into the works of others, and compiled the general mechanisms of deterioration caused by microorganisms. It took earlier research a step further than chemical characterization and

\textsuperscript{54} Chlorite sheets are mineral formations of talc and brucite. These sheets do not stack as closely and tightly as other clay minerals, allowing rhizoid and rhizine penetration.

\textsuperscript{55} Ascaso, et al. “Study of the biogenic weathering of calcareous litharenite stones cause by lichen and endolithic microorganisms,” 35.

\textsuperscript{56} Ibid, 35.

\textsuperscript{57} Ibid, 35.

discussed how the biodeterioration of stone influenced “nearly all environmentally induced degradation processes,” even after organism removal and regrowth.\textsuperscript{59} This article collects in one place, the conclusions of major discoveries and conclusions in conservation treatments. While not necessarily a new idea, it stresses the use of small scale testing before treatment and the consideration of long-term preservation in treatment plans regarding deterioration. This is an early article to propose an in situ evaluation of biological growth to understand environmental factors beyond the presence of light and water that may provide alternative methods of control that are better suited to long-term preservation than the use of chemical treatments.

In the same year as Warscheid’s review of research on biodeterioration, Tomaselli [et al.] studied the biodiversity of photosynthetic microorganisms present on stone monuments in Florence, Italy.\textsuperscript{60} It was generally known that there was a wide range of stone-dwelling organisms, but this study used a molecular approach known as Amplified Ribosomal DNA Restriction Analysis (ARDRA) to identify the strains of cyanobacteria and algae. At this time, molecular genetic techniques were relatively young, and ARDRA had been in use for less than ten years. It has since been succeeded by techniques that require much smaller samples. Analysis of ARDRA data is closely tied to phylogeny, and requires good DNA reference sequences, which is also true of newer DNA and amino acid analysis techniques.\textsuperscript{61} This study established DNA sequencing as a viable identification technique in conservation, recognizing that monitoring organisms in their natural habitats would make it easier to both assess dangerous organisms easier, and set up suitable treatment plans for containment.\textsuperscript{62} Since this study, the use of molecular techniques has become much more widespread in the identification of

\textsuperscript{60} Tomaselli, et al. “Biodiversity of photosynthetic micro-organisms dwelling on stone monuments,” 251-258.
\textsuperscript{61} Ibid, 257.
\textsuperscript{62} Ibid, 257.
microbiological growth because it is often difficult to determine species based on morphological characteristics.

In 2003, Lisci [et al.] developed a list of common plants and lichens found on historic buildings and monuments at several sites around Rome and Siena, Italy; documented the chemical and mechanical effects of plant colonization; and discussed methods of conservation.\textsuperscript{63} The results of their study and literature review identified plants as agents of deterioration, rather than protection. They pointed to emerging trend using lichen as environmental indicators, assessing the level of environmental pollution exposure, in addition to acting as deterioration agents on stone buildings and monuments. The use of lichen as environmental sensors is possible because they are sensitive to certain byproducts of the burning of fossil fuels such as sulfur dioxide, and research was forming a better understanding of the role of lichen as secondary colonizers, following algae and bacteria, but before higher plants. The authors discussed continuing research into the determination of the most damaging and the most common forms of lichen found in the built environment in order to find “weak points in the development of these plants” to aid in their control and prevention, looking to preventative actions rather than reactionary treatments.\textsuperscript{64} Up until this point, much of the literature studies the removal of lichen, mechanically or chemically, especially with the use of biocides. The transition from a reactionary type of treatment to a more holistic approach is discussed in Warscheid [et al.] in 2000, but had taken a few more years and publications to see the transition in the literature.

In 2008 the Getty Institute published Plant Biology for Cultural Heritage. It is a detailed work covering the growth of biological organisms across multiple environments, from museums to the outdoors, and multiple materials, including animal goods, paper, textiles, and stone. It is

\textsuperscript{63} Lisci, et al. “Lichens and higher plants on stone: a review,” 1-2.
\textsuperscript{64} Ibid, 15.
the product of a collaborative effort with chapters authored by experts in different fields, including biology, chemistry, conservation, and museum studies. It is a detailed source of information and is written as a resource, not a treatment guide.

English Heritage is in the process of revising and updating their Practical Building Conservation series with the stone volume released in 2012. The series serves as an introduction to various materials used in the construction of historic buildings and structures, their deterioration and conservation. Its audience includes architects, surveyors, conservators and building contractors, so the information contained in these volumes is more general than that contained in the Getty Institute's Plant Biology for Cultural Heritage. It is based on practical experience and concentrates on practical methods of repair, treatment, and maintenance. It emphasises methods of surveying and the identification of issues to address. The processes of biodeterioration are only a small fraction of those issues, and as a result their analysis of issues of biological growth beyond the aesthetic is limited.

Unlike other studies, this English approach views biological growth as beneficial instead of harmful, citing the protective action biological growth can play in regard to mechanical weathering due to driving winds and rains.65 Their major citation for the beneficial presence of biological growth such as lichen and ivy is an article published in the journal English Nature, published in 1992. In such a mild, wet climate, the aesthetics of biological growth are an important consideration when a treatment, repair, or maintenance is planned. This is in part, due to the age value of the built environment under the protection of English Heritage.66 This is counter to the trend that is seen in other European and American publications, where

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66 Ibid, 73. 
identification of biological growth is an increasingly important step in treatment and maintenance planning.

**Mechanisms of Biodeterioration**

The mechanisms of biodeterioration can vary across organisms, but they include acidic breakdown of the substrate from biological secretions, complexation of minerals through the production and secretion of chelating agents, mineral oxidation and dissolution, and the weakening of the mineral lattice through thermal cycling. This results in mechanical damage when the area in the proximity of biological growth is permanently altered in color or texture.

<table>
<thead>
<tr>
<th>Growth</th>
<th>Biogenic Acid Produced</th>
<th>Nature</th>
<th>Mineral Elements Affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algae</td>
<td>Aliphatic, dicarboxylic, hydroxy, ketonic, oxalic, and uronic acids</td>
<td>Chelating</td>
<td>Si, Al, Fe, Mn, Mg, Ca, K, Na</td>
</tr>
<tr>
<td>Bacteria</td>
<td>Carboxylic, citric, lactic, nitric, nitrous, sulfuric, and succinic acids</td>
<td>Oxidizing, reducing, and chelating</td>
<td>Fe, Ca, Mg, Si</td>
</tr>
<tr>
<td>Lichen</td>
<td>Aliphatic carboxylic, hydroxy, humic, inorganic, ketonic, lactic, oxalic, and aromatic phenolic acids</td>
<td>Chelating</td>
<td>Si, Al, Fe, K, Na, Mg, Ca, Si</td>
</tr>
<tr>
<td>Mosses</td>
<td>Aliphatic, humic, and oxalic acids</td>
<td>Chelating</td>
<td>Ca, Mg, Na, K</td>
</tr>
</tbody>
</table>

Bacteria and algae are often the first colonizers of stone, finding nutrients in particles of atmospheric pollution and plant matter deposited on stone surfaces by wind and rain. Few surfaces are immune to bacteria, so opportunistic, higher forms of biological growth find the nutrients they need in biological and chemical residues left by bacteria, known as primary producers. As they grow and their numbers increase, the groups of bacteria and algae form

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biofilms to transport nutrients and increase adhesion to the substrate. This film is inherently sticky, and also holds particles deposited by wind and rain, which results in surface stains that affect the aesthetic appearance of stone monuments and buildings. The carbon dioxide also consumed by autotrophs, organisms that convert sunlight to cellular energy reacts with water, creates carbonic acid, which can be secreted into the biofilm where it reacts with minerals in the substrate such as carbonates in marbles and dolomites, forming soluble bicarbonates. Sulfur and nitrogen fixing bacteria product sulfuric and nitric acid, respectively, both of which dissolve stone and deposit soluble salts.

Algae and bacteria, as film producing organisms, apply stress on the mineral grains to which they adhere. As the stone surface becomes rougher, the biofilm fills interstitial spaces between mineral crystals. As temperatures fluctuate, these films swell and shrink due to water content. When these films freeze and expand, they can push apart mineral grains and give the stone surface a granular texture. These loosened grains are lost through environmental factors including wind and rain, and are vulnerable to cleaning treatments that require scrubbing or heavy rinsing. Chemical weathering occurs on a small scale with biological growth, but makes stone surfaces much more susceptible to additional forms of biological growth and exacerbates the effect of physical weathering, such as through the loss of mineral grains loosened by biological growth to wind and rain.

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Figure 2.1 An example of marble undergoing degranulation due to the presence of biological growth. Note the pebbly appearance of the marble on the right, compared with the more uniform surface on the left side of the image. Photo by author; Woodlawn Cemetery, Sulzer Monument.

In addition to facilitating chemical weathering through the production of organic acids and chelating agents, fungi and lichen also participate in mechanical weathering of stone substrates through hyphae penetration, which loosens grains and causes the loss of mineral fragments. The reaction of lichen thalli on stone also creates an environment ideal for other types of biological growth, especially mosses, because through the secretion of organic acids, the lichen create a rougher surface. This roughened of surface provides enough surface area for the weak hairlike rhizoids of moss to attach.\(^7\) The hyphae of lichen thalli penetrate stone to various degrees, and because they lack the tissue differentiation of higher plants, they are subject to the same swelling and shrinking as biofilms based on temperature and the amount of water they

\(^7\) Odgers, et al. Practical Building Conservation: Stone, 75.
contain. As the thallus expands when it absorbs water, it exerts additional pressure on nearby grains, and over time these grains become loose. In some cases this results in the loss of substrate material, and the lichen may lose its foothold and fall off as well. This is one reason that winter is considered a dying off period for lichen, but not for algae and cyanobacteria, where the mass of the biofilm never reaches such a critical point.

The endolithic and crustose thalli physically alter the surface substrate the most, but significant damage is also caused by acidic thalli secretions. These are most damaging to calcareous and carbonate-based stones, where the stone matrix is readily dissolved in acidic conditions. Some species of lichen have been found to secrete compounds that can bind with basalt, granite, and biotite. A list of acids produced by lichen can be found in Table 2.1. Those identified in the family of lichen belonging to the Lecanora designation affect a wide range of archeological materials and are aggressive colonizers, causing “physico-chemical disturbances to their substrata.” In most species of this family the damage caused is mechanical before it chemical, their acidic secretions play a secondary role in deterioration.

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Mosses are more benign than previously discussed forms of biological growth. They require a layer of soil in order to colonize their substrate, but due to their lack of a root system, they are easily removed.\textsuperscript{73} However, mosses, and their cousins, liverworts, have been found to play a role in biodeterioration through their ability to form calcareous deposits.\textsuperscript{74} The plants use minerals in their stone substrate to form these deposits that serve to strengthen the lower portions of the plants and allow them to grow. This results in thicker rhizoids that are able to penetrate stone surfaces, with some species capable of depths up to five millimeters.\textsuperscript{75} Deeper penetration is possible when the surface has already been exposed to deterioration or weathering action, particularly thermal cycling and freeze damage. These actions weaken the stone surface and can increase moisture retention, which perpetuates freeze damage and helps further sustain biological growth.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{lichen.jpg}
\caption{The lichen thallus in the center of the image has peeled away from its substrate due to repeated freeze-thaw cycles. Photo by author; Woodlawn Cemetery, Birchall Monument.}
\end{figure}

\textsuperscript{73} Caneva et al. \textit{Plant Biology for Cultural Heritage: Biodeterioration and Conservation}, 87.
\textsuperscript{74} Ibid, 82.
\textsuperscript{75} Ibid, 86.
Particularly vulnerable locations for moss propagation include perpendicular joints, such as those between a statute or structure and its base, or recessed mortar joints, especially in locations that see little direct sunlight and retain a large amount of moisture and debris. In this way mosses can disrupt aesthetic lines, and expedite the deterioration of mortar, which can affect a structure’s stability if it occurs in a location such as the mortar between bricks of a wall.

Vascular plants are by far the most common and significant forms of plant growth on the planet, and can have a disastrous affect on stone and masonry structures. Extreme examples of this type of damage are seen at jungle sites in South America, of former Mayan and Incan sites, and in Cambodia at Angkor Wat. There has been a proposed classification system that ranks biological forms based on the level of danger they propose to architectural works. Lianas, long-stemmed woody vines, and trees present the most danger due to their significant life span and extensive root systems.

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All of these pathways of deterioration affect the substrate both above and below the surface. In many cases, the removal of biological growth is considered routine or preventative maintenance. Treatments include manual removal of biological growth and chemical removal. Chemical treatments aim at ensuring that the entire organism is treated, including that which sits just below the surface and would otherwise leave residue behind that would support regrowth or additional colonization. Commercially available chemical treatments include a wide variety of biocidal compounds, and no one treatment is effective on all targeted growth. Such a broad-stroke approach is more possible with regulated biocides, but these chemicals often carry warnings regarding release and disposal control, in addition to undesired toxicity that may affect the operator. With ever-increasing environmental and safety concerns, a number of cleaners targeting biological growth have reached the market.
Chapter 3: Testing program

Introduction

In order to better understand the efficacy of biological growth removers on different types of biological growth, samples of algae and cyanobacterial biofilms, lichen, and moss were collected from sites at Woodlawn Cemetery, located in the Bronx, New York. This site was chosen as a sampling area for its proximity, large area, and variety of plant life and environmental conditions.

The goal of the testing program was to identify selected biological growth and differentiate between their responses to select cleaners through developing a methodology for organism identification and working toward a more targeted use of cleaners in the treatment of biological growth. The growths were first identified and then tested in two manners: (1) biofilm samples were removed from monuments and cultured on nutrient media in petri dishes, which were tested and monitored, (2) larger lichen and moss samples, which were removed from monuments and tested and monitored. The samples were treated with several commercially available cleaners for the removal of biological growth, and the effects of each were monitored and analyzed visually. Physical changes in growths were noted throughout the cleaner application. The tested growths were monitored after rinsing to see if they were able to recover or had suffered significant damage from exposure to cause death. The application of each cleaner did not involve the scrubbing or manual removal methods that would be used in an in situ treatment of biological growth, removing physical damage as a cause for removal and organism death.

The testing program for this study has two sections: laboratory testing, which took place from February 20, 2014 to April 25, 2014; and site analysis, revisiting several sites that were part
of a previous thesis from 2011 and studying the meaning of biological growth from stone to evaluate the biological regrowth.

**Methodology**

**Organism Identification**

For the purpose of this thesis, three organisms—algae, lichen, and moss—were studied because they are classified in distinct Phylum. Each organism was identified by their common name and described by their geographic location (Bronx County, New York State) and visual characteristics (color, growth shape, and texture). With photographs and descriptions for comparison, the New York Botanical Garden’s C.V. Starr Virtual Herbarium, the Consortium of North American Lichen Herbaria, and the United States Department of Agriculture (USDA) PLANTS Database were used to identify each growth from a common name to its taxonomic genus. During the course of my research, I noted that biological growth is more commonly identified to the genus or family level rather than species, as is common in other branches of biology. In this thesis, growths were not identified by species because of a lack of visual resources to confirm the species of each of the organisms. This may be due to a lack of cataloguing of species, but it may also be the result of changes in taxonomy due to phylogeny studies and the reliance in current research on DNA identification of species of biological growth, a specialized and costly process.

**Biological Growth Sample Collection**

On February 20th and March 20th, samples of algae and cyanobacteria were removed from the Sulzer and Montgomery monuments at Woodlawn Cemetery using sterile swabs. The samples were then cultured on prepared agar plates using standard microbiologic techniques. Additional samples of algae and lichen, and samples of moss were obtained on March 20, 2014,
following rain the previous day to ensure that targeted growths were visible and viable. Algae were gathered from the marble statue of the Sulzer monument, the Lammers Monument, and the Montgomery monument. Lichens were gathered from the Sulzer monument, an “In Memoriam” mausoleum, the John Brower mausoleum, and the Birchall monument. Moss was gathered from the John Brower mausoleum, the Cole mausoleum, and the Sulzer monument.

Figure 3.1 Map of Woodlawn Cemetery. The samples sites are named and outlined in red. Each site was selected because it presented multiple samples of biological growths.
Algae & Cyanobacteria

Samples of biofilms later identified as cyanobacteria and algae were taken from the Sulzer Monument, the Lammers Monument, and the Montgomery Monument and plated on prepared petri dishes. After several days of incubation, the cultures were analyzed and the Montgomery and Sulzer samples were identified as green algae and blue green algae to be tested further. There was a high degree of contamination in the samples obtained from the Lammers Monument and the samples were not used further.

Table 3.1 Classification of identified algae.

<table>
<thead>
<tr>
<th>Site</th>
<th>Montgomery</th>
<th>Sulzer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kingdom</td>
<td>Plantae</td>
<td>Bacteria</td>
</tr>
<tr>
<td>Phylum</td>
<td>Chlorophyta</td>
<td>Cyanophyta (also called Cyanobacteria)</td>
</tr>
<tr>
<td>Class</td>
<td>Clorophyceae</td>
<td>Cyanophyceae</td>
</tr>
<tr>
<td>Order</td>
<td>Chlorococcales</td>
<td>Chroococcales</td>
</tr>
<tr>
<td>Family</td>
<td>Chlorococcaeae</td>
<td>Microcystaceae</td>
</tr>
<tr>
<td>Genus</td>
<td>Chlorococcum</td>
<td>Gloeocapsa</td>
</tr>
<tr>
<td>Common Name</td>
<td>green algae</td>
<td>blue green algae</td>
</tr>
</tbody>
</table>
Figure 3.2 Green algae cultured from the Montgomery Monument, at 200X.

Figure 3.3 Blue green algae from the Sulzer Monument, at 200X.
Lichen

Samples were removed and tested from the Birchall Monument, the Sulzer Monument, the “In Memoriam” Mausoleum, and the John Brower Mausoleum. Upon closer, microscopic examination, the xanthoparmelia lichen removed from the John Brower Mausoleum and the bench of the Sulzer Monument appear to be of the same genus, but differing species.

Table 3.2 Classification of identified lichen.

<table>
<thead>
<tr>
<th>Site</th>
<th>John Brower &amp; Sulzer (bench)</th>
<th>Birchall</th>
<th>“In Memoriam” &amp; Sulzer (granite base)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kingdom</td>
<td>Fungi</td>
<td>Fungi</td>
<td>Fungi</td>
</tr>
<tr>
<td>Phylum</td>
<td>Ascomycota</td>
<td>Ascomycota</td>
<td>Ascomycota</td>
</tr>
<tr>
<td>Class</td>
<td>Ascomycetes</td>
<td>Ascomycetes</td>
<td>Ascomycetes</td>
</tr>
<tr>
<td>Order</td>
<td>Lecanorales</td>
<td>Lecanorales</td>
<td>Lecanorales</td>
</tr>
<tr>
<td>Family</td>
<td>Parmeliaceae</td>
<td>Parmeliaceae</td>
<td>Candelariaceae</td>
</tr>
<tr>
<td>Genus</td>
<td>Xanthoparmelia</td>
<td>Flavoparmelia</td>
<td>Candelariella</td>
</tr>
<tr>
<td>Common Name</td>
<td>xanthoparmelia lichen</td>
<td>flavoparmelia lichen</td>
<td>eggyolk lichen</td>
</tr>
</tbody>
</table>

Figure 3.4 Xanthoparmelia lichen from the John Brower Mausoleum.
Figure 3.5 Xanthoparmelia lichen from the bench of the Sulzer Monument.

Figure 3.6 Flavoparmelia lichen from the Birchall Monument.
Figure 3.7 Candelariella from the “In Memoriam” Mausoleum.

Figure 3.8 Candelariella from the granite steps of the Sulzer Monument.
Moss

Samples of three different mosses were removed from the Cole Mausoleum, John Brower Mausoleum, and the Sulzer Monument.

Table 3.3 Classification of identified mosses.

<table>
<thead>
<tr>
<th>Site</th>
<th>Sulzer</th>
<th>Cole</th>
<th>John Brower</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Kingdom</strong></td>
<td>Plantae</td>
<td>Plantae</td>
<td>Plantae</td>
</tr>
<tr>
<td><strong>Phylum</strong></td>
<td>Bryophyta</td>
<td>Bryophyta</td>
<td>Bryophyta</td>
</tr>
<tr>
<td><strong>Class</strong></td>
<td>Bryopsida</td>
<td>Bryopsida</td>
<td>Bryopsida</td>
</tr>
<tr>
<td><strong>Order</strong></td>
<td>Leucodontales</td>
<td>Hypnales</td>
<td>Pottiales</td>
</tr>
<tr>
<td><strong>Family</strong></td>
<td>Hedwigiaceae</td>
<td>Amblystegiaceae</td>
<td>Pottiaceae</td>
</tr>
<tr>
<td><strong>Genus</strong></td>
<td>Hedwigia P. Beauv.</td>
<td>Amblystegium Schimp.</td>
<td>Astomum Hampe</td>
</tr>
<tr>
<td><strong>Common Name</strong></td>
<td>hedwigia moss</td>
<td>amblystegium moss</td>
<td>astomum moss</td>
</tr>
</tbody>
</table>

Figure 3.9 Hedwigia moss from the granite base of the Sulzer Monument.
Figure 3.10 Amblystegium moss from the Cole Mausoleum.

Figure 3.11 Astomum moss from the John Brower Mausoleum.

**Protocol for Laboratory Testing**\(^{77}\)

*Agar Plate Preparation*\(^{78}\)

Plates were prepared in batches of 30 or fewer as needed. Fresh plates were prepared two to three days in advance and allowed to set in a refrigerator in a sealed plastic bag to protect from

\(^{77}\) Supplies were obtained on behalf of the Historic Preservation Program at Columbia University with assistance from Norman Weiss and George Wheeler.

\(^{78}\) This protocol was based on author experience and preparation instructions provided from the Biology Department of California Polytechnic State University course MICRO 224.
contamination. The plates were kept stacked and inverted during this waiting period. Inverting the plates prevents a buildup of condensation directly on the agar surface, which can affect organism growth. The plates were prepared using the following procedure.

- Add 8.06g of nutrient agar powder to 350mL deionized water in an Erlenmeyer flask.
- Mix with a clean stirring rod to break down as many powder clumps as possible.
- Add a wooden stirring stick to avoid superheating the liquid, and cover the top of the flask with a piece of parafilm.
- Microwave for 3.5 minutes, or just until the agar boils.
- Let cool until the flask is cool enough to touch.
- Fill each petri dish approximately halfway with agar. Let cool without covering.
- Once the agar has solidified, cover the plates and invert them. Store in a cool place such as a refrigerator until they are ready for use.

Sample Plating

The swabbed biological growth samples were spread on the prepared agar plates containing standard nutrient media. The plates were incubated at room temperature next to a window for four days. Some plates showed multiple forms of growth, including fungal, mold-like growth that was determined to be an undesired organism that may have been present at the sampling site. Desired growths from each plate were replated to obtain pure cultures, using sterile procedures with a flame-sterilized nichrome loop and prepared plates. These samples were plated and propagated on nutrient agar plates. The samples were inverted and incubated at room temperature next to a window. They were examined daily to ensure that no excess moisture was building up in the plates, and that the samples were taking hold in the agar.
Plates with multiple distinct colonies of growth were replated on new separate plates and incubated and examined to ensure that each plate contained only one type of organism. The presence of algae and cyanobacteria was confirmed via microscopic analysis using an Omono microscope at 400x with a 12V/20W light source. Samples were then photographed using a Nikon microscope at 200X (combined ocular and objective lenses) with a 12V/50W light source. Characteristics of identification for the algae included their tapered round shapes such as teardrops or pointed ovals, slight green color, and lack of flagella. For the cyanobacteria, the characteristics were the same except for a smooth, rounded shape. No auxiliary staining techniques were used in identification in order to view the green color resulting from the presence of chloroplasts.

After identification, the desired samples were replated for a third time in order to have enough consistent samples for later testing. The replating process was repeated three times in order to achieve consistent growth on each plate and to propagate those desired organisms onto a sufficient number of plates for testing. The number of replating rounds required to obtain pure cultures can vary based on the fastidiousness of the desired organisms.

**Chemical Agents**

The products tested in this thesis all claim to remove biological growth or staining in their product literature (see Table 3.4). They are designed for use on stone, concrete, and even modern siding materials. Calcium hypochlorite, though not a commercial cleaner was included in this study because of its known interactions with biological organisms. Solutions of calcium

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79 Flagella are the lash-like appendages found on the cell body of certain prokaryotic and eukaryotic cells. They are not found on cyanobacteria of the Phylum Cyanobacteria, and only on select algae of Chlorophyta, in distinct sets of two and specific orientations, none of which were observed in this case.

80 Fastidious microorganisms have complex nutritional requirements and only grow in the presence of special nutrients in their culture medium. The term fastidiousness is used in this context to refer to the varying growth rates of the desired organisms based on the availability of ideal light and temperature conditions.
hypochlorite are used in paper conservation and as a cleaner for biological staining on marble statuary."81

Several available commercial cleaners were initially considered but later excluded because they contain the same active ingredient as other products. Diedrich 808X Black Encrustation Remover is a sodium hydroxide-based product with a pH of 14, much like Prosoco’s ReKlaim Cleaner Part A. As part of a system of treatment, the latter is more versatile, an important quality in an architectural cleaner, and was deemed more suitable for testing. Diedrich 101 Masonry Restorer Super Concentrate is a hydrofluoric acid and hydrochloric acid-based product with a pH of 5.3 based on the manufacturer’s maximum suggested dilution. The presence of hydrofluoric acid in 101 Masonry Restorer complicates the use of this product because of occupational safety and environmental regulations regarding its release as waste water, requiring controlled disposal following use. Hydrogen peroxide available from Fisher Science with a pH of 3, was also initially considered, but the Prosoco ReKlaim Activator, Part A is hydrogen peroxide-based, and with a pH of 4 is slightly more suitable for use on stone.

<table>
<thead>
<tr>
<th>Product name</th>
<th>Manufacturer</th>
<th>Product Classification</th>
<th>Active Ingredient</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium hypochlorite 0.78% solution</td>
<td>Fisher Science</td>
<td>Building cleaner</td>
<td>Calcium hypochlorite, Ca(ClO)(_2)</td>
<td>N/A</td>
</tr>
<tr>
<td>D/2 Biological Solution</td>
<td>deGruchy’s LimeWorks</td>
<td>Biological cleaner</td>
<td>quaternary ammonium compounds(^{82})</td>
<td>9</td>
</tr>
<tr>
<td>ReKlaim Cleaner, Part A</td>
<td>Prosoco EnviroKlean</td>
<td>Biological cleaner</td>
<td>sodium hydroxide, amine hydroxide</td>
<td>14</td>
</tr>
<tr>
<td>ReKlaim Activator, Part B</td>
<td>Prosoco EnviroKlean</td>
<td>Biological cleaner</td>
<td>hydrogen peroxide</td>
<td>4</td>
</tr>
<tr>
<td>ReVive</td>
<td>Prosoco EnviroKlean</td>
<td>Biological cleaner</td>
<td>alkyl dimethyl benzyl ammonium chlorides, ethoxylated alcohols</td>
<td>4.5</td>
</tr>
<tr>
<td>Limestone &amp; Masonry Afterwash</td>
<td>Prosoco SureKlean</td>
<td>Building cleaner</td>
<td>acetic acid</td>
<td>1</td>
</tr>
<tr>
<td>Limestone Restorer</td>
<td>Prosoco SureKlean</td>
<td>Building cleaner</td>
<td>glycolic acid, hydrochloric acid</td>
<td>1</td>
</tr>
<tr>
<td>2365 Artillery Spores and More</td>
<td>ShoreBest</td>
<td>Biological cleaner</td>
<td>potassium hydroxide, ethyl alcohol, tetrapotassium pyrophosphate</td>
<td>14</td>
</tr>
<tr>
<td>2724 ASRSafe Concrete Cleaner</td>
<td>ShoreBest</td>
<td>Building cleaner</td>
<td>potassium hydroxide</td>
<td>13.5</td>
</tr>
<tr>
<td>A990 BioShield</td>
<td>ShoreBest</td>
<td>Biostatic agent(^{83})</td>
<td>Octadecylaminodimethyltri-hydroxysilylpropylammonium chloride</td>
<td>4</td>
</tr>
</tbody>
</table>

\(^{82}\) The exact structure of these compounds is proprietary and not listed in product data.

\(^{83}\) A biostatic product is generally part of a strategy of preventing biological growth. Its presence inhibits the formation of biofilms and the attachment of spores or seeds.
Calcium hypochlorite is occasionally used in cemetery stone and statuary cleaning in dilute solutions, such as a 0.78% solution used by the Arizona Pioneer & Cemetery Restoration Project and the National Parks Service.\(^\text{84}\) It is considered gentler and less damaging that sodium hypochlorite, which is found in household bleach and may contribute sodium ions for detrimental salt formation.

D/2 Biological Solution is another product used by National Parks and by the Department of Veterans Affairs in National Cemeteries.\(^\text{85}\) Its active ingredients are similar to those in ReVive, 2365 Artillery Spores and More, and A990 BioShield, but the structure of each manufacturer’s ammonium chloride compounds are proprietary, and each product contains additives that result in a different pH. Prosoco ReVive is considered to be comparable to D/2 Biological Solution, with similar active ingredients, but based on their different pH values, there was enough difference in the proprietary formulations to warrant separate testing.

Prosoco’s ReKlaim system, formerly known as BioKlean, is a two-part system that was mixed, diluted, and tested according to manufacturer’s specifications, followed by the recommended dilution of Prosoco Limestone & Masonry Afterwash. The components of ReKlaim were also tested individually to examine the effect of each part at its supplied strength. Prosoco Limestone & Masonry Afterwash was tested because it is specified for use following the application of the ReKlaim system to neutralize the surface, and like with the individual testing of the components of ReKlaim, more information was sought in regards to the influence of this particular chemical agent on biological growth.


ShoreBest 2365 is designed for use on artillery spores\textsuperscript{86} and other biological growth found on wall cladding systems including exterior insulation and finishing systems (EIFS) and aluminum and vinyl siding, modern materials found in conjunction with stone and masonry in residential structures throughout the Northeast. ShoreBest 2365 Artillery Spores and More was included in this study based on its active ingredients and to see if its use may be suited for the removal of other forms of biological growth such those considered in this thesis.

Shorebest 2724 ASRSafe Concrete Cleaner is a cleaner designed to remove biological staining on concrete, without affecting aggregates containing silica. This product was tested because of the large amount of aging concrete that architectural conservation will have to treat around the country.

ShoreBest A990 Bioshield, whose active ingredient is octadecylaminodimethyltrial-hydroxysilylpropylammonium chloride, is used in multiple industries as a preventative treatment for odor-causing microorganisms. The product is used architecturally as a pretreatment and routine treatment of roofing materials, to prevent the growth of microorganisms that cause odor, staining, and deterioration.

**Regulation of Biocides**

Biocides have been used in the past on biological growths, especially those that are hard to remove or regrow quickly, in an effort to impart some resistance to future growth. The use of these products has always included detailed testing, due to occupational and environmental hazards, because the chemicals in biocides are often toxic to many organisms and not specific in their targets. Their heavy regulation has limited their wide-spread use, especially in architectural

\textsuperscript{86} The black spores of a fungus that grows on decaying wood and attach to light colored surfaces including vinyl siding and even car panels.
conservation, where the scale of their use can make controlled application and mitigation nearly impossible and certainly cost-prohibitive.

Technically, biocides are chemical agents capable of killing living organisms. In the United States, biocides are classified as pesticides, and fall under the regulatory jurisdiction of the United States Environmental Protection Agency (US EPA). They are defined as “(1) any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest, (2) any substance or mixture of substances intended for use as a plant regulator, defoliant, or desiccant, and (3) any nitrogen stabilizer...” and regulated under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), first passed in 1947. This law requires that any product sold as a pesticide must be registered and licensed by the US EPA. The registration and licensing process ensures that pesticides are properly labeled and will not cause unreasonable harm to the environment when used according to instructions. If this process is not completed and renewed on a cyclical basis, a product cannot be marketed as a pesticide, or in this case, a biocide. Similar regulation also applies to labels such as “antibacterial,” “antifungal,” and “antimicrobial.”

Recently, the US EPA has begun to revise its approach to the pesticide review process, altering their labeling requirements, among those, limiting what non-registered chemicals may claim. This has caused a recent move within commercial industries that supply chemicals for architectural conservation and restoration away from language suggesting pesticidal or biocidal action. Several companies such as Prosoco have renamed products whose names previously

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88 U.S. Environmental Protection Agency, “Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA).”
targeted biological growth. Examples include the re-branding of BioKlean and BioWash as ReVive and ReKlaim.

In 2013, the Environmental Protection Agency (EPA) altered its policies regarding labeling claims of pesticides, which include microbial and fungal agents.\textsuperscript{89} The EPA enacted what they call label evaluation policies, which require products to be registered with the EPA and meet certain data requirements in order to be considered antimicrobial or antifungal products. These requirements “ensure that all antimicrobial products are efficacious at any active ingredient concentration within the approved certified limits.”\textsuperscript{90} These requirements would equate these biological cleaners designed for architectural use with those used in hospitals and food production, where there is a wider diversity of microbes encountered, and sterility is an absolute necessity.

Products that do not meet tests such as AOAC Method 955.17 Fungicidal Activity Method, cannot carry an antifungal claim.\textsuperscript{91} Rather than reformulate their products to meet EPA standards for antimicrobial and antifungal products, many are seeing label and product description changes instead. This requires a better eye when reading product descriptions, and makes this thesis all the more necessary in navigating changes brought by this new product literature requirement.

There has been a separate and growing trend away from the use of US EPA registered biocides in the treatment of biological growth in conservation due to growing concern of their

\textsuperscript{91} The list of tests is available at the Antimicrobial Science Policies, Disinfectant Technical Science Section, http://www.epa.gov/oppad001/sciencepolicy.htm.
effect on the environment and increasing government regulation of such chemicals.\textsuperscript{92}

Commercial cleaners designed for the removal of general soiling are increasingly used to remove biological growth.

\textit{Biocidal Mechanisms of Cleaners}

The products in Table 3.1 contain a variety of active ingredients that affect living organisms through varying mechanisms including disruption of cellular activity through protein denaturalization and destabilization of cell membranes. Some of these chemicals are small enough that they can slip through openings in the cell membrane and interact with intracellular elements such as proteins, organelles, and DNA. Others attack the surface of the cell and cause it to lyse, breaking its membrane, causing contents to spill out, and killing the cell. Uncharged molecules are more easily passed through the cell membrane.\textsuperscript{93} Once inside a cell, weak acid compounds can dissociate, and while the acidic protons are shuttled out of the cell, a build-up of the conjugate base can build up in the cell and can disrupt cell function. Table 3.5 lists the different mechanisms of the products and chemicals included in this thesis.

<table>
<thead>
<tr>
<th>Product name</th>
<th>pH</th>
<th>Active Ingredient</th>
<th>Mechanism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium Hypochlorite, 0.78% Solution</td>
<td>N/A</td>
<td>Calcium Hypochlorite, Ca(ClO)₂</td>
<td>An oxidizing agent that denatures proteins and destabilizes cell membranes, causing cells to pop.</td>
</tr>
<tr>
<td>D/2 Biological Solution</td>
<td>9</td>
<td>quaternary ammonium compounds</td>
<td>Disrupts cell membranes.</td>
</tr>
<tr>
<td>ReKlaim Cleaner, Part A</td>
<td>14</td>
<td>sodium hydroxide, amine hydroxide</td>
<td>The high pH denatures proteins and destroys cell membranes.</td>
</tr>
<tr>
<td>ReKlaim Activator, Part B</td>
<td>4</td>
<td>hydrogen peroxide</td>
<td>An oxidative agent that denatures proteins and destabilizes cell membranes, causing cells to pop.</td>
</tr>
<tr>
<td>ReVive</td>
<td>4.5</td>
<td>alkyl dimethyl benzyl ammonium chlorides and ethoxylated alcohols</td>
<td>A quaternary ammonium compound and a cleaning agent to assist in particle removal during rinsing and prevent reformation of ruptured membranes.</td>
</tr>
<tr>
<td>Limestone &amp; Masonry Afterwash (LMA)</td>
<td>1</td>
<td>acetic acid</td>
<td>The low pH denatures proteins and destroys cell membranes.</td>
</tr>
<tr>
<td>Limestone Restorer</td>
<td>1</td>
<td>glycolic acid, hydrochloric acid</td>
<td>The low pH denatures proteins and destroys cell membranes.</td>
</tr>
<tr>
<td>2365 Artillery Spores and More</td>
<td>14</td>
<td>potassium hydroxide, ethyl alcohol, tetrapotassium pyrophosphate</td>
<td>The high pH denatures proteins and destroys cell membranes.</td>
</tr>
<tr>
<td>2724 ASRSafe Concrete Cleaner</td>
<td>13.5</td>
<td>potassium hydroxide</td>
<td>The high pH denatures proteins and destroys cell membranes.</td>
</tr>
<tr>
<td>A990 BioShield</td>
<td>4</td>
<td>Octadecylaminodimethyiltrihydroxysilylpropylammonium chloride</td>
<td>Prevents formation of biofilms by preventing the formation of peptide chains.</td>
</tr>
</tbody>
</table>

Methodology for Testing of Cleaners

Between collection and testing, the samples were routinely sprayed with water and stored in a clear covered and humidified container to keep the growths in an active state in the dry conditions of the heated laboratory. The third generation of plated algae was used to test the cleaners in order to ensure that only the desired, identified organism was tested.

Each dish was divided into four quadrants. Three of the quadrants were used as test sites for three cleaners; the fourth was left as a control site. Lichen and moss samples were placed in labeled petri dish halves. Chemical solutions were applied dropwise in specified concentrations and samples were monitored for change over thirty minutes and the samples were rinsed with water over filter paper (Figure 3.12). Each solution was applied to isolated samples of biological growths at the dilution specified by their manufacturers. The solution strength, application method, and dwell time are including in Table 3.6. In the case of the ReKlaim and Limestone & Masonry Afterwash system, each part was also tested independently to better understand the toxicity of each component of the product. In order to assess the efficacy at killing biological growth, each chemical agent was applied for up to thirty minutes before it was rinsed off over filter paper. The filter paper was used to catch loosened pieces of the samples and ensure that the majority of the sample was recovered after rinsing. The pieces caught in the filter paper were then transferred to a damp petri dish half and placed back in a humidified container (Figure 3.13). This washing was not possible with the plated samples of algae, so after the dwell time, excess solution was wicked off the sample area with a Kim Wipe and the area was plated again to see if any of the affected organisms were still viable.
Observations made during and after testing were recorded by growth and cleaner. Table 3.7 shows observations for lichen growths; Table 3.8 for moss growths; and Table 3.9 for algal growths.

Figure 3.12 Samples were rinsed in filter flasks with #2 filter paper until the pH of the standing water was the same as the tap water used for rinsing.

Figure 3.13 Container where samples were stored throughout testing. A second piece of clear plastic was placed over the other half of the container and samples were sprayed with water daily. Wet paper towels were also placed in the container to maintain a constant humidity.
Table 3.6 Table of application methods for each cleaner. Where directed use calls for dilutions, the strongest recommended dilution is used, with the weakest dilution indicated in parenthesis.

<table>
<thead>
<tr>
<th>Chemical Agent</th>
<th>Application Method</th>
<th>Dwell Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium Hypochlorite, Ca(ClO)₂</td>
<td>0.78% solution prepared and added dropwise to a dry sample.</td>
<td>15 minutes</td>
</tr>
<tr>
<td>D/2 Biological Solution</td>
<td>Applied undiluted. Added dropwise to a dry sample.</td>
<td>30 minutes</td>
</tr>
<tr>
<td>ReKlaim Cleaner, Part A</td>
<td>Applied undiluted. Added dropwise to a dry sample.</td>
<td>30 minutes</td>
</tr>
<tr>
<td>ReKlaim Activator, Part B</td>
<td>Applied undiluted. Added dropwise to a dry sample.</td>
<td>30 minutes</td>
</tr>
<tr>
<td>ReKlaim System</td>
<td>1 part Cleaner, 1 part Activator, 3 parts water. Added dropwise to a dry sample.</td>
<td>30 minutes</td>
</tr>
</tbody>
</table>
| ReKlaim System with Limestone & Masonry Afterwash    | 1 part Cleaner, 1 part Activator, 3 parts water. Added dropwise to a dry sample.  | ReKlaim: 30 minutes  
Rinsed after 30 minutes and Afterwash added dropwise to wet sample.  
Afterwash: 10 minutes |
| ReVive                                               | Applied undiluted. (1:10 dilution possible) Added dropwise to a dry sample.         | 30 minutes     |
| Limestone & Masonry Afterwash                        | 1 part Afterwash, 1 part water. Added dropwise to a dry sample.                    | 15 minutes     |
| Limestone Restorer                                   | 1 part Restorer, 2 parts water (up to 1:6 dilution possible). Added dropwise to a dry sample.  | 30 minutes     |
| 2365 Artillery Spores and More                       | Applied undiluted (up to 1:5 dilution possible). Added dropwise to a dry sample.   | 30 minutes     |
| 2724 ASRSafe Concrete Cleaner                       | Applied undiluted (up to 1:5 dilution possible). Added dropwise to a dry sample.   | 30 minutes     |
| A990 BioShield                                       | Applied undiluted. Added dropwise to a dry sample.                                 | 30 minutes     |
Chapter 4: Results and Observations.

The testing of lichen and moss samples were completed between March 29, 2014 and April 8, 2014. Due to their plated nature, the algae samples required a longer growth time before testing could take place, so it was conducted separately, on April 23, 2014.

Lichen and Moss

Full observations made during lichen and moss testing were recorded in a table found in Appendix C, with images of each sample taken before testing, immediately after, and 48 hours after testing (Figure 4.1 and Figure 4.2). The immediate reaction of growth samples upon application to each product can be found in Appendix C. Observations on the effect of treatment over time were recorded by growth in Tables 4.1, 4.2 and 4.3.

<table>
<thead>
<tr>
<th>Before treatment</th>
<th>After rinsing</th>
<th>After 48 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Image" /></td>
<td><img src="image2" alt="Image" /></td>
<td><img src="image3" alt="Image" /></td>
</tr>
</tbody>
</table>

**Figure 4.1** Xanthoparmelia lichen from the bench at the Sulzer Monument tested with 2365 Artillery Spores and More.

<table>
<thead>
<tr>
<th>Before treatment</th>
<th>After rinsing</th>
<th>After 48 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image4" alt="Image" /></td>
<td><img src="image5" alt="Image" /></td>
<td><img src="image6" alt="Image" /></td>
</tr>
</tbody>
</table>

**Figure 4.2** Hedwigia moss from the granite base of the Sulzer Monument tested with 2365 Artillery Spores and More.
After 48 hours, nearly all samples showed some impact from treatment. The results were ranked on the number of Eggyolk lichen from the “In Memoriam” and Sulzer monuments and hedwiga moss from the Sulzer monument were the most resistant growths. The flavoparmelia lichen and amblystegium moss from the Cole mausoleum were the most vulnerable. Overall, the lichen samples were overall more vulnerable than the mosses to chemical attack. Physical changes observed with each sample based on observations in Tables 4.1 and 4.2. The least effective product was A990 BioShield, because none of the samples showed any change 48 hours after testing. The ReKlaim system followed by Limestone & Masonry Afterwash was the most effective, with the highest effect on samples.
<table>
<thead>
<tr>
<th>Categorization</th>
<th>Building Cleaners</th>
<th>Biostatic Agent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium Hypochlorite 0.78% solution</td>
<td>LMA</td>
<td>ReKlaim System and LMA</td>
</tr>
<tr>
<td>pH</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Xanthoparmelia caligata (Blechnum)</td>
<td>2365 Acrelone</td>
<td>ReVose</td>
</tr>
<tr>
<td>13.5</td>
<td>Product A</td>
<td>4</td>
</tr>
<tr>
<td>2724 ASSR Safe Concrete Cleaner</td>
<td>Product B</td>
<td>5</td>
</tr>
<tr>
<td>9</td>
<td>Wetting Agent</td>
<td>4</td>
</tr>
<tr>
<td>14</td>
<td>BioShield</td>
<td>14</td>
</tr>
<tr>
<td>4</td>
<td>Biostatic Agent</td>
<td>4</td>
</tr>
</tbody>
</table>

### Table 4.1 Observations of treatment on lichen samples.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Initial color</th>
<th>After 48 hours</th>
<th>After 48 hours</th>
<th>After 48 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vigorous bubbling followed application</td>
<td>Yellowed and browned</td>
<td>Browned only slightly</td>
<td>Browned, turned brown and brittle</td>
<td>Transparent green, which yellowed over 48 hours</td>
</tr>
<tr>
<td>Vigorous bubbling followed application</td>
<td>Green</td>
<td>Browned</td>
<td>Browned, turned brown and brittle</td>
<td>Transparent green</td>
</tr>
<tr>
<td>Vigorous bubbling followed application</td>
<td>Yellow</td>
<td>Browned</td>
<td>Browned, turned brown and brittle</td>
<td>Transparent green</td>
</tr>
<tr>
<td>Vigorous bubbling followed application</td>
<td>Yellow</td>
<td>Browned</td>
<td>Browned, turned brown and brittle</td>
<td>Transparent green</td>
</tr>
<tr>
<td>Vigorous bubbling followed application</td>
<td>Yellow</td>
<td>Yellowed</td>
<td>Yellowed</td>
<td>Transparent green</td>
</tr>
<tr>
<td>Vigorous bubbling followed application</td>
<td>Yellow</td>
<td>Browned</td>
<td>Browned, turned brown and brittle</td>
<td>Transparent green</td>
</tr>
<tr>
<td>Vigorous bubbling followed application</td>
<td>Yellow</td>
<td>Browned</td>
<td>Browned, turned brown and brittle</td>
<td>Transparent green</td>
</tr>
<tr>
<td>Vigorous bubbling followed application</td>
<td>Yellow</td>
<td>Browned</td>
<td>Browned, turned brown and brittle</td>
<td>Transparent green</td>
</tr>
</tbody>
</table>

**Observations:**
- Initial treatment turned the growth a transparent green. After 48 hours, the growth had significantly shrunk and darkened in color.
- Initial treatment turned the growth yellowed over 48 hours. During that time the sample also became brittle, shrunk and yellowed in some areas.
- Some bubbling occurred following application. After 48 hours the growth displayed yellowing and browning.
- Initial treatment turned the growth a transparent green, which yellowed over 48 hours.
- Some bubbling occurred following application. After 48 hours the growth displayed yellowing and browning.
- Little change observed after treatment. A few growth displayed significant shrinkage and embrittlement. It was also yellowed in some areas.
- Initial application turned the growth transparent green. After 48 hours, the growth was bright green. Some areas still appeared yellowed. Little color change was observed, but little shrinkage was observed.
- Initial application turned the growth bright green. Some areas began to turn darker brown, but the growth was bright green. There was little color change, but the surface began to appear translucent and waxy. After 48 hours the growth was no longer shrunk and curled. The growth was very brittle and had begun cracking.
- Initial application turned the growth greenish brown. Some areas began to turn darker brown, but other areas still appeared green. The growth was bright green and had curled on itself, and there were cracks from the leaf edge into the thallus.
- Initial application turned the growth bright green. No drastic visible changes were observed after 48 hours.
- Initial treatment did not turn the growth bright green. No drastic visible changes were observed after 48 hours.

**Changes:**
- Following treatment, the growth appeared significantly more yellowed. After 48 hours, the growth showed more yellowing, in addition to embrittlement and shrinking.
- Following treatment, the growth appeared significantly more yellowed. After 48 hours, the growth showed more yellowing, in addition to embrittlement and shrinking.
- Following treatment, the growth appeared significantly more yellowed. After 48 hours, the growth showed more yellowing, in addition to embrittlement and shrinking.
- Following treatment, the growth appeared significantly more yellowed. After 48 hours, the growth showed more yellowing, in addition to embrittlement and shrinking.

**Conclusion:**
- The growth turned a light yellow color and shrunk. After 48 hours, the growth was a pale brownish green.
- The growth turned a light yellow color and shrunk. After 48 hours, the growth was a pale brownish green.
- The growth turned a light yellow color and shrunk. After 48 hours, the growth was a pale brownish green.
- The growth turned a light yellow color and shrunk. After 48 hours, the growth was a pale brownish green.

**Notes:**
- Following treatment, the growth appeared significantly more yellowed. After 48 hours, the growth showed more yellowing, in addition to embrittlement and shrinking.
- Following treatment, the growth appeared significantly more yellowed. After 48 hours, the growth showed more yellowing, in addition to embrittlement and shrinking.
- Following treatment, the growth appeared significantly more yellowed. After 48 hours, the growth showed more yellowing, in addition to embrittlement and shrinking.
- Following treatment, the growth appeared significantly more yellowed. After 48 hours, the growth showed more yellowing, in addition to embrittlement and shrinking.

**Further Observations:**
- After 48 hours, the growth had turned to a green color. After 48 hours, the growth had turned to a green color. After 48 hours, the growth had turned to a green color. After 48 hours, the growth had turned to a green color.
- After 48 hours, the growth had turned to a green color. After 48 hours, the growth had turned to a green color. After 48 hours, the growth had turned to a green color. After 48 hours, the growth had turned to a green color.
- After 48 hours, the growth had turned to a green color. After 48 hours, the growth had turned to a green color. After 48 hours, the growth had turned to a green color. After 48 hours, the growth had turned to a green color.
- After 48 hours, the growth had turned to a green color. After 48 hours, the growth had turned to a green color. After 48 hours, the growth had turned to a green color. After 48 hours, the growth had turned to a green color.
### Table 4.2 Observations of treatment on moss samples.

<table>
<thead>
<tr>
<th>Category</th>
<th>Products</th>
<th>Biological Cleaners</th>
<th>Building Cleaners</th>
<th>Calcium Hypochlorite 0.78% solution</th>
<th>LMA</th>
<th>Limestone Restorer</th>
<th>2724 ASRSafe Concrete Cleaner</th>
<th>D2 Biological Solution</th>
<th>ReKlaim Cleaner, Part A</th>
<th>ReKlaim Activator, Part B</th>
<th>ReKlaim System</th>
<th>ReKlaim System and LMA</th>
<th>ReVire</th>
<th>236J Artillery Spares and More</th>
<th>A990 BioShield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hedwigia moss</td>
<td>Calcium Hypochlorite 0.78% solution</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Hedwigia moss</td>
<td>Calcium Hypochlorite 0.78% solution</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Hedwigia moss</td>
<td>Calcium Hypochlorite 0.78% solution</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Hedwigia moss</td>
<td>Calcium Hypochlorite 0.78% solution</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Astomum moss</td>
<td>Calcium Hypochlorite 0.78% solution</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Astomum moss</td>
<td>Calcium Hypochlorite 0.78% solution</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<td>N/A</td>
</tr>
<tr>
<td>Astomum moss</td>
<td>Calcium Hypochlorite 0.78% solution</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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</tbody>
</table>
*Algae*

Each sample plate of algae was divided into sixths in order to allow for duplicate tests of each cleaner. The deep yellow color and opacity of the plates are due to the presence of microbiological growth. These plates are the third generation of plated organisms, and were microscopically identified as described in Chapter 3 (Figure 3.2 and Figure 3.3). The plates outlined in green are green algae samples, and those outlined in blue are blue-green algae (cyanobacteria) samples. Due to the inability to rinse samples or adequately remove traces of the cleaners, it was decided to exclude testing the ReKlaim followed by Limestone & Masonry Afterwash. Images of individual plates before testing can be found in Appendix C. After testing, each area was sampled and replated to check for regrowth on freshly prepared plates and photographed after 24 and 48 hours.

*Figure 4.3* Set 1 of test plates, containing test areas for calcium hypochlorite, D/2, ReKlaim parts A and B, and ReKlaim system. Photographed immediately after product application.
Figure 4.4 Set 2 of test plates, containing test areas for LMA, Limestone Restorer (LR), 2365 Artillery Spores and More, 2724 ASRSafe Concrete Cleaner, A990 BioShield, and ReVive. Photographed before product application.

Figure 4.5 All replated test areas after 24 hours.
Figure 4.6 All replated test areas after 48 hours. Algae samples are outlined in green and cyanobacteria samples are outlined in blue. Outlined in red are the two of the four samples tested with ReVive showed no viable regrowth.

After 48 hours, nearly all replated samples showed signs of new, viable growth. There was some variation in the size of the new microbiological colonies, but growth was consistent and not due to contamination (Figure 4.6). The results of these tests were ranked based on whether the replated area showed viable growth (Table 4.4). Two areas that did not show significant regrowth were one replated site of green algae and a replated site of blue-green algae treated with ReVive.
### Table 4.3 Regrowth of algal samples after treatment

<table>
<thead>
<tr>
<th>Categorization</th>
<th>Building Cleaners</th>
<th>Biostatic Agent</th>
<th>Products</th>
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</thead>
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<tr>
<td></td>
<td>Calcium Hypochlorite</td>
<td>LMA</td>
<td>LMA</td>
</tr>
<tr>
<td>Active Ingredient</td>
<td>Ca(ClO)(_2) (0.78%) solution</td>
<td>Limestone Restorer</td>
<td>2724 ASRSafe</td>
</tr>
<tr>
<td>pH</td>
<td>N/A</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Green algae (Montgomery)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Blue-green algae (Sulzer)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>acetic acid</td>
<td>glycolic acid, hydrochloric acid</td>
<td>potassium hydroxide</td>
</tr>
</tbody>
</table>
Chapter 5: Analysis of Results and Conclusions.

Analysis

Each cleaner was ranked on a scale of 0 to 3, based on how it affected each growth. Those that received a rank of 3 caused discoloration, shrinking, and other physical deformation. A ranking of two was given for cleaners that caused two of the three mentioned changes. A ranking of one was given when only one change resulted, and zero was given where treatment resulted in no changes to the sample. These ranks were based on the observations recorded in Appendix C.

Table 5.1 Ranking and determining characteristics used in analysis.

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<thead>
<tr>
<th>Rank</th>
<th>Characteristic</th>
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<tr>
<td>3</td>
<td>Color change, shrinkage, and other physical deformation.</td>
</tr>
<tr>
<td>2</td>
<td>Two of the previous characteristics.</td>
</tr>
<tr>
<td>1</td>
<td>One of the previous characteristics / Regrowth present.</td>
</tr>
<tr>
<td>0</td>
<td>No change / No regrowth present.</td>
</tr>
</tbody>
</table>

Table 5.2 Ranked performance of products with algae. Samples that showed regrowth showed no change after treatment.

<table>
<thead>
<tr>
<th>Categorization</th>
<th>Building Cleaners</th>
<th>Biological Cleaners</th>
<th>Biostatic Agent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ca(ClO)₂</td>
<td>LMA</td>
<td>Limestone Restorer</td>
</tr>
<tr>
<td>pH</td>
<td>N/A</td>
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<td>1</td>
</tr>
<tr>
<td>Green algae (Montgomery)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Blue-green algae (Sulzer)</td>
<td>0</td>
<td>0</td>
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There are several visible trends in the performance of each cleaner based on the varying forms of biological growth. Of the three types of growth tested algal growths appear to be the most resistant to the cleaners; lichen appear to be least resistant; and moss falls somewhere in the middle. This confirms that different forms of biological growth are better suited for surviving chemical attack. This is most likely the result of the different morphologies of algae, lichen, and moss. Where lichen do not have defined tissues, each cell of the thallus is essentially the same,
there is slightly more order and differentiation in mosses. This may have assisted the mosses in resisting damage from the cleaning products. The resistance of the algal growths most likely be attributed to their morphology as biofilms. These films are more likely to bear the brunt of chemical damage from cleaners and limit the exposure of viable cells to chemical agents.

The two eggyolk lichen, from the granite base of the Sulzer Monument and the “In Memoriam” Mausoleum, showed very similar results with less variation than those between other lichen growths. This was expected due to their identification within the same genus, and very similar microscopic appearance. The two xanarthoparmelia lichen also had similar reactions to the cleaners, with the largest difference being the response to calcium hypochlorite. In both cases this may be due to a difference in species, with such identifying characteristics influencing the resistance of each growth. These varied degrees of alteration require further testing to determine a relationship between the particular biological growth and cleaner.

The building cleaner products caused more significant cell death than the biological growth cleaners, which was expected due to their harsh chemical compositions. Limestone & Masonry Afterwash was highly effective on lichen, but only moderately effective on moss. The opposite trend was seen with calcium hypochlorite, which was more effective on moss samples than lichen samples. In this case, the separation of functions into different cellular organs may have been a disadvantage, with the energy-producing chlorophyll concentrated in the moss leaves, which are thinner than the lichen thallus and more susceptible to chemical injury. This may be why the leafier moss, the amblystegium moss, was more affected by treatment than the two other, woodier mosses. Hedwigia moss, which showed the clearest differentiation between root, branch, and leaf systems was the most resistant growth tested, showing loss of color but little physical deformation during testing.
Limestone Restorer was not as effective as Limestone & Masonry Afterwash, despite having the same pH. The active ingredients in Limestone Restorer are inorganic acids, where the active ingredient in Limestone & Masonry Afterwash is an organic acid. This likely affects the cellular uptake of each of the chemicals, which would allow for more internal damage to be caused by Limestone & Masonry Afterwash and resulting in more effective cleaning of biological growth. On lichen, 2724 ASRSafe Concrete Cleaner performed better than calcium hypochlorite, and shows the effect of high-pH treatments such as those also categorized as biological growth cleaners.

The most consistently effective product was the ReKlaim system followed by Limestone & Masonry Afterwash, which is categorized as a biological growth cleaner. Unlike the other products tested, this treatment system consists of an alkaline solution that is followed by an acidic solution neutralizer. Both alkaline and acidic conditions affect cell membranes, and it is likely that the alkaline exposure weakens the cells (which is also observed in the use of 2365 Artillery Spores and More, and ReKlaim Part A), and caused the samples to be more vulnerable to treatment with Limestone & Masonry Afterwash. Use of this system caused at least two characteristics of cell death including color change, shrinkage, and cracking in all samples except the hedwigia moss, which only experienced a color change.

The difference in performance of D/2 Biological Solution and ReVive is notable because they are very similarly formulated as quaternary ammonium based cleaners. D/2 Biological Solution was much more effective than ReVive in both the lichen and moss tests, with ReVive leaving approximately one third of the samples unaffected whereas the D/2 affected each growth to some degree. This may be because the pH of D/2 Biological Solution is closer to neutral (pH=7) than ReVive. The pH scale is an indicator of acidity, the presence of dissociated
hydrogen ions (H\(^+\)), and alkalinity, the presence of excess dissociated hydroxyl groups (OH\(^-\)). Because uncharged molecules are more easily passed through the cell membrane, more components of D/2 Biological Solution were able to enter the cell, and build-up would have impeded cellular functions more than ReVive. These mechanisms are the result of internal cellular reactions, which is not the case with cleaners acting through high/low pH-driven mechanisms and discussed separately.

The performance of ReKlaim Part A was very similar to 2724 ASRSafe Concrete Cleaner, as alkaline, hydroxide-based products. It is interesting to note that the addition of ReKlaim Part B, which did not significantly lower the pH, caused a significant change in performance, especially in the case of the amblystegium moss from the Cole Mausoleum, which was unaffected by the combined ReKlaim system, but vulnerable to both constituents. This result was not expected, but is consistent with the better performance of the ReKlaim and Limestone & Masonry Afterwash system.

The 2365 Artillery Spores and More was the second most effective cleaner after the ReKlaim system and Limestone & Masonry Afterwash. This may be due to the additional active ingredients which are not strong bases and do not contribute to the pH to the degree of the potassium hydroxide. The ethyl alcohol and tetrapotassium pyrophosphate are both capable of passing through the cell membrane—the alcohol because it acts very similar to water and tetrapotassium pyrophosphate through ion channels like salts to maintain equilibrium. These would contribute to the drying and shrinking and embrittlement of many of the samples. While this product is designed for use on the spores of artillery lichen which were not tested in this thesis, it’s performance in this testing program shows the potential for a wider, effective use of this product.
The least effective product tested was A990 BioShield. As a biostatic agent it does not interact with biological growth the same way as the other products tested here. It is designed to prevent biological growth after application on a clean surface by inhibiting the formation of biofilms. In order to examine its use as a preventative treatment, further research must be undertaken.

At first glance, the alkaline cleaners were more effective than the acidic cleaners. However, a difference of one in pH is the equivalent of an order of magnitude, or a factor of 10. On this scale, a pH of 7 is neutral and extends from 0 to 14. Those cleaners with a pH of 1 are one thousand more times acidic than those with a pH of 4. The alkaline cleaners are relatively more basic, with pHs of 13.5 and 14, than the acidic cleaners are acidic, with pHs of 4, which may be a factor in the higher success rate of alkaline products.
Chapter 6: Biological Regrowth Evaluation

Introduction

In 2011, a fellow Historic Preservation student, S. Caitlin vonHedemann, wrote a thesis called “Cleaning Biological Growth on Stone: A Study of Current Cleaners.” Due to the limited timeline for the completion of her thesis work, the long-term results were unanalyzed. In an effort to look at the long-term results of biological growth cleaners, the areas tested by vonHedemann were examined three years after cleaning as part of this thesis to analyze the potential for regrowth after cleaning. VonHedemann compared the performance of D/2 Biological Solution, Prosoco’s Sure Klean BioKlean (now called ReKlaim), Prosoco’s Sure Klean BioWash (now called ReVive), CB-4, Prestór Gel, and combinations of Prestór Gel with CB-4, BioWash, and D/2 at the following locations:

- North facade belt course of the Metropolitan Museum of Art, New York, NY
- Fuentidueña Apse of the Metropolitan Museum of Art: The Cloisters, New York, NY
- Bronx Victory Memorial, Pelham Bay Park, Bronx, NY

North facade belt course of the Metropolitan Museum of Art

The north facade of the Metropolitan Museum of Art was designed by the firm McKim, Mead, and White, and constructed of Indiana limestone in 1911. It is part of an addition including the north and south wings designed by the firm for the museum.
Before cleaning in 2011

The limestone of the north facade beltcourse had significant green staining in protected surfaces not subject to direct water runoff.

Following cleaning, vonHeledemann noted that areas cleaned with BioKlean (ReKlaim) appeared cleaner and “remained the brightest” after four months. The 2011 treatment with BioKlean (ReKlaim) included neutralization with Limestone & Masonry Afterwash. This is consistent with the results obtained in this thesis, where the ReKlaim system and Limestone & Masonry Afterwash treatment resulted in the highest number of physical changes linked to cell death in the biological growth samples.

Figure 6.1 The north facade beltcourse before cleaning.

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After cleaning in 2011

Figure 6.2 North beltcourse four months after cleaning.\textsuperscript{97}

In 2014

In 2014 the cleaned portion of the north beltcourse has almost returned to its original state, stained with biological growth. The 2011 cleaning test sites are not readily visible, but upon closer examination the test areas for BioKlean and CB-4 (10 minutes) can be discerned on the stone.

The uncleaned portion of the north beltcourse of the Metropolitan Museum of Art is darker than the tested areas east on the beltcourse, with a more uniform pattern of biological growth and serves as a point of comparison and shows what the cleaned beltcourse would look like if no action had been taken. There is a small difference between the cleaned and uncleaned portion, but without knowing that any sort of cleaning had taken place, the difference could be attributed to as exposure differences. The uncleaned west end of the facade sits further within Central Park, and closer to a small group of trees separating the museum side entrance from the 86th Street Transverse. These trees would provide, shade, nutrients, and a source for biological growth.

\textsuperscript{97} vonHedemann, “Cleaning biological growth on stone: a study of current cleaners,” 32.
**Figure 6.3** Cleaned portion of the north beltcourse three years after cleaning. The approximate location of each test site is outlined in alternating color for visibility. Two of the test areas are still just discernable. They are the sites cleaned with BioKlean on the left and CB-4 for 10 minutes on the right. Photo by author.

**Figure 6.4** Uncleaned portion of the north beltcourse, west of the cleaned area on the same facade. Photo by author.
The Fuentidueña Apse is a built-in chapel at The Cloisters, an annex of the Metropolitan Museum of Art that holds many of the Museum’s medieval works. The chapel was built in the 12th century of local Fuentidueña limestone. In 1958 the chapel was removed from its original location at the Church of San Martin at Fuentidueña near Segovia, Spain and installed at its current site at Fort Tryon Park, overlooking the Hudson River.

Today the base of the apse displays grey soiling, in addition to small lichen colonies. The surface of the stone is very rough from physical weathering, past conservation treatments, and biodeterioration. The rough, weathered stone surface provides an ideal environment for the spreading of biofilms and the attachment of lichen. The friable nature of the deteriorated surface

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can inhibit removal if the surface cannot be scrubbed, which can loosen biological growth and increase the efficacy of many cleaners.

In 2011 vonHedemann identified the dark grey areas that turned bright green after wetting as small bodies of moss. However, based on their slightly rounded, flat bodies, and the strength of their physical attachment to the stone surface, they are more likely a species of lichen growing in the presence of biofilms of algae or cyanobacteria. This would account for both the dark grey staining and small bodies of biological growth. Previous studies have noted the presence of grey-black films of cyanobacteria were “widespread on marble and travertine stoneworks exposed to sun irradiation.” Similar conditions were observed at Woodlawn Cemetery in 2014, on the deteriorated surface of a marble statue.

*Before cleaning in 2011*

![Figure 6.6 Northwest exterior wall of the apse before cleaning.](image)

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100 vonHedemann, “Cleaning biological growth on stone: a study of current cleaners,” 34.
After cleaning in 2011

The apse was subjected to both wet and gel-based treatments, with varying success. VonHedemann noted that the gel treatments removed biological growth, in addition to pieces of stone. She noted that the best gel cleaning was achieved with Prestór Gel alone, and the best wet treatment was achieved with D/2 Biological Solution.

![Figure 6.7](image) Northwest exterior wall of the apse after cleaning.\(^{103}\)

In 2014

The areas cleaned in 2011 still stand out in stark contrast to the uncleaned areas around them. There has been a significant change in the appearance of the results since 2011 and in the environment of the area tested since 2011. In the years since the cleaning, the area cleaned by BioWash (ReKlaim) mixed with Prestór Gel appears to have been the most successful cleaning test. The tree vonHedemann describes as providing shade for most of the day was recently removed, leaving the area more exposed and allowing for more direct sunlight. This seems to have inhibited the regrowth of the biological growths. The direct sunlight creates a harsh, dry environment for most microorganisms, which is why they are more often found in damp or shady locations where water more consistently available. The absence of significant biological growth

\(^{103}\) vonHedemann, “Cleaning biological growth on stone: a study of current cleaners,” 35.
in the vicinity has prevented recolonization of the test sites, which stand out more today than they did after cleaning in 2011.

**Figure 6.8** Cleaned portion of the northwest exterior wall three years after cleaning. All of the test areas are clearly visible, unlike along the north facade beltcourse at the Metropolitan Museum of Art. Photo by author.
The Bronx Victory Memorial is a tribute to the Bronx soldiers that served in World War I. It was installed in Pelham Bay Park in 1932. It is constructed of Cordova Texas limestone, with a gilded bronze statue at the top of its column.\textsuperscript{104}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{bronx_victory_memorial.jpg}
\caption{The Bronx Victory Memorial sits within Pelham Bay Park in the Bronx and faces northwest along Bruckner Boulevard, which runs through the park. Photo by author.}
\end{figure}

\textsuperscript{104} von Hedemann, “Cleaning biological growth on stone: a study of current cleaners,” 36.
Before cleaning in 2011

Figure 6.9 The east side of the southwestern wing of the memorial.\textsuperscript{105}

A few years prior to testing in 2011, the base of the memorial was treated with pressure washing and honing to remove surface staining from past treatments and acts of vandalism. Based on photos of the biological growth taken by vonHedemann prior to treatment, the stone appears to have been colonized by a species of crustose dot lichen, which adhere close to the surface of stone and penetrate it to a certain degree, based on species.

After cleaning in 2011

Figure 6.10 The limestone base of the east side of the southwest wing after cleaning.\textsuperscript{106}

\textsuperscript{105} vonHedemann, “Cleaning biological growth on stone: a study of current cleaners,” 36.
\textsuperscript{106} Ibid, 37.
After cleaning in 2011, vonHedemann noted that the Texas limestone showed little improvement after treatment, with both the staining and biological growth proving resistant.\textsuperscript{107} The stone was more deteriorated than stone at the other test sites. The applications that included Prestór Gel pulled away stone fragments in addition to biological growth upon removal.\textsuperscript{108} VonHedemann notes that the wet treatments were even less successful.\textsuperscript{109}

\textit{In 2014}

There was little success in cleaning the growths in 2011, and much like the test area at the Metropolitan Museum of Art, there is no evidence of vonHedemann’s cleaning tests. This may be due to several factors, including a more recent cleaning. This site has been plagued with a history of vandalism and strong cleaning methods to remove graffiti. The memorial is also situated between a thickly landscaped park and a roadway. There does not appear to be any significant biological colonization of the surface, and the dark stains on the limestone base appear to come from another source. The park has seen significant landscape changes. There are a large number of new, young trees that have been planted in the last year--many still have their nursery tags. There are also signs that trees have been removed, and marks suggesting that more trees may be replaced soon. The proximity of changing landscaping and a decrease in the amount of shade around the memorial could easily influence the regrowth of biological growth.

\textsuperscript{107}vonHedemann, “Cleaning biological growth on stone: a study of current cleaners,” 37.
\textsuperscript{108}Ibid, 37.
\textsuperscript{109}Ibid, 37.
The sites tested in 2011 by vonHedemann show a range of stages of biological regrowth. There is no longer any evidence of the cleaning tests at the Bronx Victory Memorial, but the sites at the Metropolitan Museum of Art and Fuentidueña Apse show varying levels of regrowth. A major factor in the level of regrowth appears to be due to the influence of the local environment. The two sites that sit within parks and in close proximity to trees, the Bronx Victory Memorial and the Metropolitan Museum of Art, show significant regrowth. They are in much closer proximity to trees and other larger forms of biological growth, with windblown particles serving as a source of stone inoculation and promoting regrowth. There are trees present in Fort Tryon Park, where the Fuentidueña Apse is located, but are further away from the cleaning test sites than the other two sites. The removal of trees in the vicinity seems to inhibit regrowth and may serve as a viable solution to slowing the growth of microorganisms and biological growth.

Another source of biological regrowth, especially in the case of the beltcourse at the Metropolitan Museum of Art may be the control panels between each testing area. These

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Figure 6.11 The east side of the southwest wing of the memorial three years after cleaning. Photo by author.

Conclusions

uncleaned areas likely contained the same organisms, and once the surface had been cleared of growth, it was recolonized by nearby organisms. The cleaning that took place at the Metropolitan Museum of Art does not appear to be as thorough as that at the Fuentidueña Apse. In the 2011 after photos, the limestone at the apse is much more even in color than the sites at the Metropolitan Museum of Art or the Bronx Victory Memorial.
Chapter 7: Final Conclusions

This thesis shows that there is a correlation between the efficacy of cleaners and biological growth, which can be utilize in designing economical and effective treatment plans. The three growth types tested are among the most common found on buildings and monuments, and the products tested are popular amongst architectural conservators and readily available. Lichenous growths were the most vulnerable to the tested products, and those labeled as building cleaners generally had a more significant effect on all growth samples. Algal growths were resistant to all except one of the products (ReVive), and showed viable regrowth after testing, which may limit the long-term efficacy of such localized cleaning treatments. The mosses were more vulnerable to biological growth cleaners, and fell in between lichen and algal films for overall product resistance.

Continuation of this research will assist conservators in designing custom treatment plans to address biological growth on buildings and monuments. By understanding how popular products react with biological growth, we can more efficiently and successfully treat undesired biological growth for a lasting result. The prevention of regrowth is an important aspect of a successful treatment plan, especially when periodic retreatment is difficult or costly. Targeted treatment plans, guided by previously gained knowledge on product performance, will help ensure that conservators are providing the best, most effective service possible. The resources required for the continuation and application of this research are easily accessible with extensive databases such as the New York Botanical Garden’s C.V. Starr Virtual Herbarium, the Consortium of North American Lichen Herbaria, and the USDA PLANTS Database all available for free online.

The relationship between cleaners and biological growth needs to be explored with further sampling and testing to include additional identified forms of biological growth.
Initially both algae and lichen samples were plated and distinct differences were observed between the resulting plated growths, which were expected. First, the lichen took to the plates much faster than the algae, showing distinct colonies in 48 hours, whereas the algae took twice as long. This also required longer growth times for algal films before organisms could be successfully grown, isolated, identified, and testing. Two reasons for the differences in growth time could be bacterial contamination from the thallus, or a preference in the fungal component of the lichen for the nutrient media. When examined microscopically, there was little to suggest the presence of fungal cells in the second generation of cultures. Rather, there was a higher instance of bacterial contamination in those samples, possibly due to the presence of bacteria on the surface of the lichen thallus. However, as the algae and fungal cells were not observed growing together, or in a lichenized form, these plates were not explored further and were discarded.

There is no one nutrient medium suitable for all microorganisms, and finding the ideal one often involves trial and error. Other media that are used for the incubation of fungi on agar include potato dextrose agar and nutrient agar with lactic acid. These types of agar include additional complex organic molecules such as starches that aid in the growth of fungi, and inhibit the growth of bacteria, such as lactic acid.

More research should be done to improve the methodology for the testing of biofilms such as algae and cyanobacteria. With more time, a simulation of these films on stone would provide more ideal laboratory testing conditions. More selective nutrient media would also be interesting to explore and encourage quicker organism procreation than stone slabs, but, as found

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in this thesis, there are issues of contamination and the issue of multiple organism isolation and identification, both of which were encountered in this thesis.

Consistent algae and cyanobacteria growths were difficult to isolate, an issue which should be addressed if they are included in future testing. As the organisms responsible for difficult-to-remove organic staining on stone, differences in their responses to available products should be explored further.

Additional research should be conducted looking at the efficacy of the recommended dilutions of the products tested in this thesis. This would be especially useful in examining the performance of products with a very high or very low pH with additional active ingredients that do not significantly contribute to the pH as in the case of 2365 Artillery Spores and More. Bringing each product to a closer pH would better simulate safe and practical use of each product and provide a better comparison to those products with mid-range pH values. This would also be beneficial because the use of products with mid-range pH values is more desirable due to concerns that solutions of high and low pH may erode the stone substrate.

This thesis did not examine the role of mechanical action in biological growth removal. Incorporation of this element into a research methodology would further inform treatment plans in architectural conservation. It would also provide an opportunity to examine the efficacy of biostatic products such as A990 BioShield, which could be applied following cleaning and monitored to determine how it performs as a preventative treatment in different environments.

The effect of the products tested on stone was also not examined, but which is an integral part of the product selection process for any cleaning. The research in this thesis does not seek to replace site testing of products, simply to augment the knowledge used in selecting which products to test.
Bibliography


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Appendix A. Terms

Biofilm: Noun, an aggregate of microorganisms in which cells are frequently embedded with a self-produced matrix of extracellular polymeric substance (EPS) adhere to each other and/or a surface. The EPS is generally composed of extracellular DNA, proteins, and polysaccharides.

Cytoplasm: the substance within the cell membrane, but excluding the nucleus; contains organelles, vesicles, and other inclusions.

Diaspore: a plant dispersal unit containing a seed or spore, plus any additional tissues that assist in dispersal.

Eukaryote: an organism whose cells contain a nucleus and other organelles enclosed in membranes.

Heterotroph: the opposite of an autotroph. an organism that relies on environmental organic carbon for growth.

Lithobiotic: used to describe microbial communities that inhabit stone. These organisms may use inorganic compounds as nutrients.

Lyse: to undergo lysis, the destruction of the cell membrane through bacterial, osmotic, or physical means, killing the cell and spilling its contents.

Mycobiont: the fungal component of lichen.

Non-vascular plant: a type of macrobiological growth that depends on its environment for a water supply and cannot store it within its body. There are no cellular distinctions like in vascular plants, which have three basic plant organs: roots, stems, and leaves.

Photoautotroph: an organism that use light as their primary energy source and can reduce carbon dioxide, usually through photosynthesis, to make complex organic compounds to create and store
energy. Because of their ability to form complex organic compounds, which are relied on by other organisms for growth, photoautotrophs are considered primary producers. The opposite of a phototroph is a heterotroph, which relies on organic carbon compounds for growth.

Photobiont: the photosynthetic component of lichen.

Phylogenetic: based on evolutionary relationships.

Prokaryote: any organism that lacks a membrane-bound nucleus.

Taxonomic: the process or system of describing the way in which different living things are related by putting them in groups

Taxa: plural of taxon; a taxonomic group or entity; the name applied to a taxonomic group in a formal system of nomenclature.

Thallus: the undifferentiated vegetative tissue of some organisms such as algae, fungi, liverworts, and lichen.
Appendix B. Photographs of samples and sample sites.

Algae

Montgomery Monument

Figure B.1. Montgomery Monument with the test area outlined in red.

Figure B.2. Close-up of the test area on the Montgomery Monument.
Marble statue at the Sulzer Monument

Figure B.3. Marble statue of Clara I. Sulzer at the Sulzer Monument with the test area outlined in red.

Figure B.4. Test area on the marble statue of the Sulzer Monument.
Lichen
John Brower Mausoleum

Figure B.5. John Brower Mausoleum.

B: 3
Figure B.6. Walkway to the John Brower Mausoleum with the lichen removed for testing outlined in red.
Bench at the Sulzer Monument.

Figure B.7. Bench at the Sulzer Monument with the growth removed for testing outlined in red.

Figure B.8. Seat of the bench at the Sulzer Monument with the lichen removed for testing outlined in red.
Birchall Monument

**Figure B.9.** The Birchall Monument, with the growth removed for testing outlined in red.

**Figure B.10.** Close-up of the lichen removed for testing.
Figure B.11. The In Memoriam Mausoleum, with the growth removed for testing outlined in red.
Figure B.12. Close-up of the lichen removed for testing.
Steps at the base of the Sulzer Monument.

**Figure B.13.** The steps at the base of the Sulzer monument, with the growth removed for testing outlined in red.

**Figure B.14.** Close-up of the lichen removed for testing.
Moss
Cole Mausoleum

Figure B.15. Main façade of the Cole Mausoleum, facing north.
Figure B.16. Moss-covered wall of the Cole Mausoleum, facing east.

Figure B.17. Close-up of the moss removed for testing outlined in red.
John Brower Mausoleum

Figure B.18. Area of moss growth with the growth removed for testing outlined in red.

Figure B.19. Close-up of the moss removed for testing outlined in red.
Steps at the base of the Sulzer Monument

Figure B.20. Area of moss growth with the growth removed for testing outlined in red.

Figure B.21. Close-up of the moss removed for testing.
Appendix C. Photographs of testing and results.

Algae

Figure C.1. Algae sample replated after testing with 2365Artillery Spores and More. Note the spread of the growth across the plate into the control area.

Figure C.2. Algae sample replated after testing with 2724 ASRSafe Concrete Cleaner and D/2 Biological Solution.
**Figure C.3.** Algae sample replated after testing with Limestone and Masonry Afterwash and calcium hypochlorite.

**Figure C.4.** Algae sample replated after testing with A990 BioShield and Limestone Restorer.
Figure C.5. Algae sample replated after testing with ReKlaim Part A and ReKlaim Part B.

Figure C.6. Algae sample replated after testing with ReKlaim system and ReVive.
Figure C.7. Cyanobacteria tested with 2365 Artillery Spores and More. Note the spread of the growth across the plate into the control area.

Figure C.8. Cyanobacteria tested with 2724 ASRSafe Concrete Cleaner and D/2 Biological Solution.
**Figure C.9.** Cyanobacteria tested with Limestone and Masonry Afterwash and calcium hypochlorite.

**Figure C.10.** Cyanobacteria tested with A990 BioShield and Limestone Restorer.
Figure C.11. Cyanobacteria tested with ReKlaim Part A and ReKlaim Part B.

Figure C.10. Cyanobacteria tested with ReVive and ReKlaim System.
Lichen

Birchall Monument
Flavoparmelia lichen
2365 Artillery Spores and More

Before treatment

After treatment

48 hours after treatment
Birchall Monument
Flavoparmelia lichen
2724 ASRSafe Concrete Cleaner

Before treatment

After treatment

48 hours after treatment
Birchall Monument
Flavoparmelia lichen
A990 Surface Protectant

Before treatment

After treatment

48 hours after treatment

C: 9
Birchall Monument
Flavoparmelia lichen
Calcium hypochlorite

Before treatment

After treatment

48 hours after treatment
Birchall Monument
Flavoparmelia lichen
D/2 Biological Solution

Before treatment

After treatment

48 hours after treatment
Before treatment

After treatment

48 hours after treatment

Birchall Monument
Flavoparmelia lichen
Limestone Restorer
Before treatment

After treatment

48 hours after treatment

Birchall Monument
Flavoparmelia lichen
ReKlaim System followed by
Limestone & Masonry Afterwash
Birchall Monument
Flavoparmelia lichen
ReKlaim Part A

Before treatment

After treatment

48 hours after treatment
Before treatment

After treatment

48 hours after treatment

Birchall Monument
Flavoparmelia lichen
ReKlaim Part B

C: 16
Before treatment

After treatment

48 hours after treatment

Birchall Monument
Flavoparmelia lichen
ReKlaim System
Birchall Monument
Flavoparmelia lichen
ReVive

Before treatment

After treatment

48 hours after treatment

C: 18
Brower Mausoleum
Xanthoparmelia lichen
2365 Artillery Spores and More

Before treatment

After treatment

48 hours after treatment
Brower Mausoleum
Xanthoparmelia lichen
2724 ASRSafe Concrete Cleaner

Before treatment

After treatment

48 hours after treatment
Brower Mausoleum
Xanthoparmelia lichen
A990 BioShield

Before treatment

After treatment

48 hours after treatment
Brower Mausoleum
Xanthoparmelia lichen
Limestone and Masonry Afterwash

Before treatment

After treatment

48 hours after treatment
Brower Mausoleum
Xanthoparmelia lichen
ReKlaim Part A

Before treatment

After treatment

48 hours after treatment
Before treatment

After treatment

48 hours after treatment

Brower Mausoleum
Xanthoparmelia lichen
ReKlaim Part B
Brower Mausoleum
Xanthoparmelia lichen
ReKlaim System followed by
Limestone & Masonry Afterwash

Before treatment

After treatment

48 hours after treatment
Brower Monument
Xanthoparmelia lichen
Revive

Before treatment

After treatment

48 hours after treatment

C: 30
Before treatment

After treatment

48 hours after treatment

In Memoriam Mausoleum
Eggyolk Lichen
2365 Artillery Spores and More
In Memoriam Mausoleum
Eggyolk Lichen
2724 ASR Safe Concrete Cleaner

Before treatment

After treatment

48 hours after treatment

C: 32
In Memoriam Mausoleum
Eggyolk Lichen
A990 Surface Protectant

Before treatment

After treatment

48 hours after treatment

C: 33
In Memoriam Mausoleum
Eggyolk Lichen
Calcium hypochlorite

Before treatment

After treatment

48 hours after treatment
In Memoriam Mausoleum
Eggyolk Lichen
D/2 Biological Solution

Before treatment

After treatment

48 hours after treatment

C: 35
In Memoriam Mausoleum
Eggyolk Lichen
Limestone Restorer

Before treatment

After treatment

48 hours after treatment
In Memoriam Mausoleum
Eggyolk Lichen
ReKlaim Part A

Before treatment

After treatment

48 hours after treatment

C: 37
In Memoriam Mausoleum
Eggyolk Lichen
ReKlaim System followed by
Limestone & Masonry Afterwash

Before treatment

After treatment

48 hours after treatment

C: 38
In Memoriam Mausoleum
Eggyolk Lichen
ReKlaim Part B

Before treatment

After treatment

48 hours after treatment
In Memoriam Mausoleum
Eggyolk Lichen
ReKlaim System

Before treatment

After treatment

48 hours after treatment

C: 40
In Memoriam Mausoleum
Eggyolk Lichen
ReVive

Before treatment

After treatment

48 hours after treatment

C: 41
In Memoriam Mausoleum
Eggyolk Lichen
Limestone & Masonry Afterwash

Before treatment

After treatment

48 hours after treatment

C: 42
Sulzer Monument Bench
Xanthoparmelia lichen
2365 Artillery Spores and More

Before treatment

After treatment

48 hours after treatment

C: 43
Sulzer Monument Bench
Xanthoparmelia lichen
2724 ASRSafe Concrete Cleaner

Before treatment

After treatment

48 hours after treatment
Sulzer Monument Bench
Xanthoparmelia lichen
A990 BioShield

Before treatment

After treatment

48 hours after treatment

C: 45
Sulzer Monument Bench
Xanthoparmelia lichen
Calcium hypochlorite

Before treatment

After treatment

48 hours after treatment

C: 46
Before treatment

After treatment

48 hours after treatment

Sulzer Monument Bench
Xanthoparmelia lichen
D/2 Biological Solution

C: 47
Sulzer Monument Bench
Xanthoparmelia lichen
Limestone Restorer

Before treatment

After treatment

48 hours after treatment

C: 49
Sulzer Monument Bench
Xanthoparmelia lichen
ReKlaim Part B

Before treatment

After treatment

48 hours after treatment
Sulzer Monument Bench
Xanthoparmelia lichen
ReKlaim System followed by
Limestone & Masonry Afterwash

Before treatment

After treatment

48 hours after treatment
Sulzer Monument Bench
Xanthoparmelia lichen
ReKlaim System

Before treatment

After treatment

48 hours after treatment
Sulzer Monument Bench
Xanthoparmelia lichen
Revive

Before treatment

After treatment

48 hours after treatment

C: 54
Sulzer Monument
Eggyolk lichen
2365 Artillery Spores and More

Before treatment

After treatment

48 hours after treatment
Sulzer Monument
Eggolk lichen
2724 ASRSafe Concrete Cleaner

Before treatment

After treatment

48 hours after treatment

C: 56
Sulzer Monument
Egg yolk lichen
A990 BioShield

Before treatment

After treatment

48 hours after treatment

C: 57
Sulzer Monument
Eggyolk lichen
Calcium hypochlorite

Before treatment

After treatment

48 hours after treatment
Sulzer Monument
Eggyolk lichen
D/2 Biological Solution

Before treatment

After treatment

48 hours after treatment

C: 59
Sulzer Monument
Eggyolk lichen
Limestone and Masonry Afterwash

Before treatment

After treatment

48 hours after treatment

C: 60
Sulzer Monument
Eggyolk lichen
Limestone Restorer

Before treatment

After treatment

48 hours after treatment
Sulzer Monument
Eggyolk lichen
ReKlaim Part A

Before treatment

After treatment

48 hours after treatment

C: 62
Before treatment

After treatment

48 hours after treatment

Sulzer Monument
Egg yolk lichen
ReKlaim Part B
Sulzer Monument
Eggyolk lichen
ReKlaim System followed by
Limestone & Masonry Afterwash

Before treatment

After treatment

48 hours after treatment
Sulzer Monument
Eggyolk lichen
ReKlaim System

Before treatment

After treatment

48 hours after treatment

C: 65
Before treatment

After treatment

48 hours after treatment

C: 66
Moss

John Brower Mausoleum
Astomum moss
2365 Artillery Spores and More

Before treatment

After treatment

48 hours after treatment
John Brower Mausoleum
Astomum moss
2724 ASRSafe Concrete Cleaner

Before treatment

After treatment

48 hours after treatment

C: 68
John Brower Mausoleum
Astomum moss
A990 BioShield

Before treatment

After treatment

48 hours after treatment
John Brower Mausoleum
Astomum moss
Calcium hypochlorite

Before treatment

After treatment

48 hours after treatment

C: 70
John Brower Mausoleum
Astomum moss
D/2 Biological Solution

Before treatment

After treatment

48 hours after treatment
Before treatment

John Brower Mausoleum
Astomum moss
Limestone and Masonry Afterwash

After treatment

48 hours after treatment

C: 72
Before treatment

After treatment

48 hours after treatment
Before treatment

After treatment

48 hours after treatment
John Brower Mausoleum
Astomum moss
ReKlaim System followed by
Limestone & Masonry Afterwash

Before treatment

After treatment

48 hours after treatment

C: 76
John Brower Mausoleum
Astomum moss
ReKlaim System

Before treatment

After treatment

48 hours after treatment

C: 77
John Brower Mausoleum
Astomum moss
Revive

Before treatment

After treatment

48 hours after treatment
Cole Mausoleum
Amblystegium moss
2365 Artillery Spores and More

Before treatment

After treatment

48 hours after treatment

C: 79
Cole Mausoleum
Amblystegium moss
2724 ASRSafe Concrete Cleaner

Before treatment

After treatment

48 hours after treatment
Cole Mausoleum
Amblystegium moss
A990 BioShield

Before treatment

After treatment

48 hours after treatment
Cole Mausoleum
Amblystegium moss
Calcium Hypochlorite

Before treatment

After treatment

48 hours after treatment
Cole Mausoleum
Amblystegium moss
D/2 Biological Solution

Before treatment

After treatment

48 hours after treatment

C: 83
Before treatment

Cole Mausoleum
Amblystegium moss
Limestone and Masonry Afterwash

After treatment

48 hours after treatment
Cole Mausoleum
Amblystegium moss
ReKlaim Part A

Before treatment

After treatment

48 hours after treatment

C: 86
Cole Mausoleum
Amblystegium moss
ReKlaim Part B

Before treatment

After treatment

48 hours after treatment

C: 87
Before treatment

After treatment

48 hours after treatment
Cole Mausoleum
Amblystegium moss
ReKlaim System

Before treatment

After treatment

48 hours after treatment
Cole Mausoleum
Amblystegium moss
Revive

Before treatment

After treatment

48 hours after treatment
Sulzer Monument
Hedwigia moss
2724 ASRSafe Concrete Cleaner

Before treatment

After treatment

48 hours after treatment

C: 92
Sulzer Monument
Hedwigia moss
Calcium hypochlorite

Before treatment

After treatment

48 hours after treatment

C: 94
Sulzer Monument
Hedwigia moss
D/2 Biological Solution

Before treatment

After treatment

48 hours after treatment
Sulzer Monument
Hedwigia moss
Limestone and Masonry Afterwash

Before treatment

After treatment

48 hours after treatment
<table>
<thead>
<tr>
<th>Time</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before treatment</td>
<td></td>
</tr>
<tr>
<td>After treatment</td>
<td></td>
</tr>
<tr>
<td>48 hours after treatment</td>
<td></td>
</tr>
</tbody>
</table>
Before treatment

After treatment

48 hours after treatment

Sulzer Monument
Hedwigia moss
ReKlaim Part A
Sulzer Monument
Hedwigia moss
ReKlaim System followed by
Limestone & Masonry Afterwash

Before treatment

After treatment

48 hours after treatment
<table>
<thead>
<tr>
<th>Time</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before treatment</td>
<td>Before photo of moss</td>
</tr>
<tr>
<td>After treatment</td>
<td>After photo of treated moss</td>
</tr>
<tr>
<td>48 hours after</td>
<td>Moss after 48 hours on treated</td>
</tr>
</tbody>
</table>

Sulzer Monument
Hedwigia moss
ReKlaim System
Before treatment

After treatment

48 hours after treatment

Sulzer Monument
Hedwigia moss
Revive
Table C.1. Notes made on cleaners during the testing of lichen and moss.

<table>
<thead>
<tr>
<th>Product</th>
<th>Active Ingredient</th>
<th>pH</th>
<th>Observations Upon Application</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Building Cleaners</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium Hypochlorite 0.78% solution</td>
<td>Ca(ClO)₂</td>
<td>N/A</td>
<td>Very easy to make, with just as strong a bleach odor.</td>
</tr>
<tr>
<td>Limestone &amp; Masonry Afterwash (LMA)</td>
<td>acetic acid</td>
<td>1</td>
<td>Strong vinegar odor.</td>
</tr>
<tr>
<td>Limestone Restorer</td>
<td>glycolic acid, hydrochloric acid</td>
<td>1</td>
<td>During initial rinsing it was observed.</td>
</tr>
<tr>
<td>2724 ASRSafe Concrete Cleaner</td>
<td>potassium hydroxide</td>
<td>13.5</td>
<td>During rinsing it was more difficult to reach the pH of tap water.</td>
</tr>
<tr>
<td><strong>Biological Cleaners</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D/2 Biological Solution</td>
<td>quaternary ammonium compounds</td>
<td>9</td>
<td>Application intensified green color in growths.</td>
</tr>
<tr>
<td>ReKlaim Cleaner, Part A</td>
<td>sodium hydroxide, amine hydroxide</td>
<td>14</td>
<td>Formed amber rings in solution around growth during testing.</td>
</tr>
<tr>
<td>ReKlaim Activator, Part B</td>
<td>hydrogen peroxide</td>
<td>4</td>
<td>Bubbles appeared immediately on every sample, but the degree to which they continued varied.</td>
</tr>
<tr>
<td>ReKlaim System</td>
<td>hydroxides and peroxide</td>
<td>13</td>
<td>Bubbles appeared immediately on every sample, but the degree to which they continued varied.</td>
</tr>
<tr>
<td>ReKlaim System followed w/ LMA</td>
<td>hydroxide and peroxide followed by acetic acid to neutralize</td>
<td>N/A</td>
<td>The addition of LMA made it more difficult to rinse to a neutral pH than either just LMA or just ReKlaim system.</td>
</tr>
<tr>
<td>ReVive</td>
<td>alkyl dimethyl benzyl ammonium chlorides, ethoxylated alcohols</td>
<td>4.5</td>
<td>Intensified the green color of some growths.</td>
</tr>
<tr>
<td>2365 Artillery Spores and More</td>
<td>potassium hydroxide, ethyl alcohol, tetrapotassium pyrophosphate</td>
<td>14</td>
<td>Formed amber rings around samples in solution during testing. During rinsing it was more difficult to reach the pH of tap water.</td>
</tr>
<tr>
<td><strong>Biostatic Agent</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A990 BioShield</td>
<td>Octadecylaminodimethyltrihydroxyethylammonium chloride</td>
<td>4</td>
<td>Growths that commonly separated during rinsing stayed together better after treatment.</td>
</tr>
</tbody>
</table>
### Table C.2. Section 1 of testing observations.

<table>
<thead>
<tr>
<th>Products</th>
<th>Building Cleaners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active Ingredient</td>
<td>Calcium Hypochlorite 0.78% solution</td>
</tr>
<tr>
<td>pH</td>
<td>N/A</td>
</tr>
</tbody>
</table>

| Green algae (Montgomery) | Reacted with the agar, causing it to swell. | Reacted with the agar, causing it to swell. |
| Blue-green algae (Sulzer) | Reacted with the agar, causing it to swell. | Reacted with the agar, causing it to swell. |

| Xanthoparmelia lichen (Sulzer) | Vigorous bubbling followed application. The edges began to brown and lighten after only a few minutes. After 48 hours the growth had yellowed and browned completely. It was brittle and had shrunk and completely curled on itself. | Application turned the growth a pale brownish green, and gave it a waxy appearance. After 48 hours the growth was a light brown color and shrunk significantly. | Treatment turned the thallus varying shades of brown and tan. After 48 hours the growth was brown, with no green, and had shrunk significantly. | Initial treatment turned the growth a transparent green and caused it to swell in size. After 48 hours the growth shrank smaller than its original size and was dark green in color. |
| Xanthoparmelia lichen (Brower) | Vigorous bubbling followed application. The edges began to brown and lighten after only a few minutes. After 48 hours the growth had yellowed and browned completely. It was brittle and had shrunk slightly. | Following treatment the growth appeared significantly more yellowed. After 48 hours, the growth showed more yellowing, in addition to embrittlement and shrinking. | After treatment growth appeared yellowed and already curled on itself. After 48 hours there was significant yellowing, shrinking, and embrittlement. | Initial treatment turned the growth a transparent green. After 48 hours, the growth had significantly shrunk and darkened in color. |
| Eggolk lichen (Sulzer) | Vigorous bubbling followed application. The growth lost all green color during treatment. After 48 hours it had shrunk and curled on itself. A small amount of green coloring returned, with the growth appearing a more bleached green than before treatment. | The growth had lost a significant amount of green color in the previously affected areas, but had not turned completely brown and had maintained its original size. | Initial application turned the growth bright green. The areas with the most exposure then turned brown. After 48 hours the growth appeared bleached, with a green haze in some areas. The growth was brittle and had curled up on itself. | Initial treatment caused the growth to swell and turn bright green. After 48 hours the sample was brittle and showed sharper edges. The sample had shrunk and curled, and maintained a dark green color. |
| Flavoparmelia lichen (Birchall) | Vigorous bubbling followed application. The growth turned a sickly shade of green and yellow. After 48 hours nearly all green color was lost, and the growth was brittle and brown. | Significant browning occurred at the thallus edges. After 48 hours the entire growth was a bleached tan color and was very brittle. | Treatment turned some areas of the thallus brown. After 48 hours the growth had shrunk and become brittle. Green color was not regained, the whole sample appeared brown. | Initial treatment turned the growth a transparent green. After 48 hours, the growth had significantly shrunk and darkened in color. |
| Xanthoparmelia lichen (Montgomery) | Discoloration appeared within 5 minutes of application. After 48 hours, the growth had yellowed completely, and become brittle, but maintained its original size. | Following treatment the growth appeared significantly more yellowed. After 48 hours, the growth showed more yellowing, in addition to embrittlement and shrinking. | Initial treatment turned the growth a transparent green. After 48 hours, the growth had significantly shrunk and darkened in color. | Initial treatment turned the growth a transparent green. After 48 hours, the growth had significantly shrunk and darkened in color. |
| Hedwigia moss (Sulzer) | Discoloration appeared within 5 minutes of application. After 48 hours, the growth had yellowed completely, and become brittle, but maintained its original size. | Treatment turned the growth brown, losing all green color. This change was permanent after 48 hours, with no green visible. | Treatment turned the growth brown, losing most of its green color. This change was permanent after 48 hours with the few green areas losing their color and appearing brown. | Growth lost all green color, turning completely brown. After 48 hours this was still the case, with no green left on the sample. |
| Amblystegium moss (Cole) | Discoloration appeared within 5 minutes of application. After 48 hours, the growth had yellowed completely, and become brittle. Shrinkage did occur. | Application turned the growth a brownish green. After 48 hours the growth had shrunk considerably and was a dark brown. | Treatment turned the growth a transparent brown, which was still observed after 48 hours. The growth had also shrunk considerably. | Turned the growth a very dark green with some areas such as branch tips turning brown. After 48 hours more of the growth had turned brown and had shrunk. |
| Astomum moss (Brower) | Discoloration appeared within 5 minutes of application. After 48 hours, the growth had yellowed completely, and become brittle, and some shrinking was observed. | Treatment turned the growth brown, losing all green color. This change was permanent after 48 hours, with no green visible. | Treatment turned the growth brown, losing all green color. This change was permanent after 48 hours, with no green visible. | After 48 hours, very little change. Some browning at branch tips. |

**Chemical Notes:** Very easy to make, with just as strong a bleach odor. During rinsing it was more difficult to reach the pH of tap water to ensure complete rinsing.
<table>
<thead>
<tr>
<th>Categorization</th>
<th>Active Ingredient</th>
<th>D/2 Biological Solution</th>
<th>ReKlaim Cleaner, Part A</th>
<th>ReKlaim Activator, Part B</th>
<th>ReKlaim System</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>pH 9</td>
<td>sodium hydroxide, amine hydroxide</td>
<td>hydrogen peroxide</td>
<td>hydroxide and peroxide</td>
</tr>
<tr>
<td>Green algae</td>
<td>quaternary ammonium compounds</td>
<td>14</td>
<td>4</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>(Montgomery)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue-green algae</td>
<td>sodium hydroxide, amine hydroxide</td>
<td>14</td>
<td>4</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>(Sulzer)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Xanthoparmelia lichen (Sulzer)</td>
<td>Growth turned dark green. After 48 hours the growth had browned slightly and had shrunk and become very brittle.</td>
<td>Turned growth transparent, bright green. After 48 hours the growth shrank significantly and turned brown and brittle.</td>
<td>Vigorous bubbling followed application. The growth turned brown on some edges. After 48 hours the growth was a pale green and had shrunk in size.</td>
<td>Treatment turned the growth varying shades of bright green. After 48 hours there was significant shrinking and tearing of the thallus. Some of the edges had yellowed, and the growth was a muddy green.</td>
<td></td>
</tr>
<tr>
<td>Eggyolk lichen (Sulzer)</td>
<td>Turned growth bright green. After 48 hours the growth had browned only slightly, maintaining most of its green color but had shrunk significantly.</td>
<td>Turned growth transparent, bright green. After 48 hours the growth shrunk significantly and turned brown and brittle.</td>
<td>Violent bubbling followed application, with enough force to break the growth apart. There was little visible change after 48 hours</td>
<td>Initial treatment turned growth a transparent dark green, which yellowed over 48 hours. Some shrinking and embrittlement was observed.</td>
<td></td>
</tr>
<tr>
<td>Xanthoparmelia lichen (Birchall)</td>
<td>Growth turned dark green. After 48 hours the growth had browned slightly and had shrunk and become very brittle.</td>
<td>Turned growth bright green, transparent in some areas. After 48 hours the growth had shrunken considerably and turned a dark green. The thallus had dried and curled on itself in sharp-looking points.</td>
<td>Vigorous bubbling followed application. A very small strip of browning occurred during treatment, along a torn edge. After 48 hours there was no evidence of browning, and almost no evidence of treatment remained. Initial color and size were maintained.</td>
<td>Application caused growth to swell considerably and also turn bright green. Waxy nodules appeared on the surface of the thallus after rinsing. After 48 hours the growth turned a yellowed green and shrunk considerably. It was also very brittle. The process of shrinking caused the thallus to crack and curl in several places, resulting in a growth with little resemblance to its original appearance.</td>
<td></td>
</tr>
<tr>
<td>Flosparmelia lichen (Birchall)</td>
<td>Growth turned bright green after application. After 48 hours, the growth was dry and brittle. It had shrunk and begun to curl on itself.</td>
<td>Growth turned yellow-green after application. After 48 hours, it had shrunk in size and become brittle. The growth was a dark yellowish green.</td>
<td>Violent bubbling followed application, tearing the growth in some places. Large yellowed areas appeared and the growth was limp and fragile. After 48 hours it had become brittle and shrunken significantly in size, in addition to curling around itself. Yellowed areas were still visible.</td>
<td>Growth turned bright green and yellowed at its edges. After 48 hours, those yellowed areas had dried and curled. The growth was waxy in appearance, and was brittle and had begun cracking.</td>
<td></td>
</tr>
<tr>
<td>Eggyolk lichen (In Mem.)</td>
<td>Green color intensified after application, and was maintained after 48 hours.</td>
<td>Initial treatment turned the growth green. After 48 hours it had shrunk, turning a muddy green.</td>
<td>Vigorous bubbling followed application. There was no visible change in the growth after 48 hours.</td>
<td>Initial treatment turned growth a transparent green, which yellowed over 48 hours.</td>
<td></td>
</tr>
<tr>
<td>Hedwigia moss (Sulzer)</td>
<td>Green color intensified after application, and was maintained after 48 hours. There was some slight browning on the branch tips.</td>
<td>Turned growth transparent brown. After 48 hours some of the color loss was permanent, with other areas returning to green.</td>
<td>Violent bubbling followed application. There was no visible change in the growth after 48 hours.</td>
<td>Turned growth a bright green. Some browning was observed at the tips. After 48 hours both the bright green and brown tips remained.</td>
<td></td>
</tr>
<tr>
<td>Amblystegium moss (Cole)</td>
<td>Green color intensified after application, but after 48 hours there was no observable change.</td>
<td>Turned growth transparent brown. After 48 hours some of the color loss was permanent, with little returning to green. Significant shrinking was observed.</td>
<td>Violent bubbling followed application. Turned leaf tips light green. After 48 hours the growth was the same initial green, but had shrunk.</td>
<td>Application caused growth to swell and turn a muddy green. After 48 hours the outer leaves on the branches were brittle and brown. A little green remained, scattered through the sample.</td>
<td></td>
</tr>
<tr>
<td>Asstomum moss (Brower)</td>
<td>Green color intensified after application, and was maintained after 48 hours. There was some slight browning on leaf tips.</td>
<td>Turned growth transparent brown. After 48 hours some of the color loss was permanent, with other areas returning to green. Some shrinking was observed.</td>
<td>Violent bubbling followed application. After 48 hours significant shrinking occurred.</td>
<td>Initial treatment turned growth a transparent green, which yellowed in some areas over 48 hours. Other areas maintained their green color.</td>
<td></td>
</tr>
</tbody>
</table>
| Chemical Notes | intensified green color in growths. | Formed amber rings in solution around growth during testing. | bubbles appeared immediately on every sample, but the degree to which they continues varied.
Table C.4. Section 3 of testing observations.

| Products | Biostatic Agent | Biological Cleaners | ReVive | 2365 Artillery Spores and More | ReKlaim System and Limestone & Masonry Afterwash | Limestone & Masonry Afterwash | Products
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>4.5</td>
<td>14</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>pH</td>
</tr>
<tr>
<td>Green algae (Montgomery)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue-green algae (Suber)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Xanthoparmelia lichen (Suber)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eggvyk lichen (Suber)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Xanthoparmelia lichen (Brower)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flavoparmelia lichen (Birchall)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eggvyk lichen (Mem.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hedwigia moss (Suber)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amblystegium moss (Cole)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Astomum moss (Brower)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical Notes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The addition of afterwash made it more difficult to rinse to a neutral pH than either just LMA or just ReKlaim system.

formed amber rings around samples in solution during testing. During rinsing it was more difficult to reach the pH of tap water to ensure complete rinsing.
### Table C.5. Complete table of ranked product performance.

<table>
<thead>
<tr>
<th>Products</th>
<th>Ca(ClO)₂ 0.78% solution</th>
<th>D/2</th>
<th>ReKlaim, Part A</th>
<th>ReKlaim, Part B</th>
<th>ReKlaim System</th>
<th>ReKlaim System w/ LMA</th>
<th>ReVive</th>
<th>LMA</th>
<th>Limestone Restorer</th>
<th>2365</th>
<th>2724</th>
<th>A990</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>N/A</td>
<td>1</td>
<td>1</td>
<td>13.5</td>
<td>9</td>
<td>14</td>
<td>4</td>
<td>13</td>
<td>N/A</td>
<td>4.5</td>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td>Green algae (Montgomery)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Blue-green algae (Sulzer)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Eggyolk lichen (In Mem.)</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>0</td>
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<tr>
<td>Eggyolk lichen (Sulzer)</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Flavopamelia lichen (Birchall)</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Xanthopamelia lichen (Birchall)</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Xanthoparmelia lichen (Sulzer)</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Amblystegium moss (Cole)</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Astomum moss (Brower)</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Hedwigia moss (Sulzer)</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
Appendix D. Photographs of reference growths.

*Algae*

Figure D.1 Cyanobacteria, known as blue-green algae. Photo courtesy of the Culture Collection of Algae at University of Texas, Austin.\(^1\)

Figure D.2 Green algae. Photo courtesy of the Culture Collection of Algae at University of Texas, Austin.

Figure D.3. Xanthoparmelia lichen. Image courtesy of The Royal Botanic Gardens and Domain Trust.

Figure D.4. Flavoparmelia lichen. Image courtesy of Sasata, Wikimedia Commons.
Figure D.5. Candelariella lichen. Image courtesy of Frantisek Bouda, BioLibrary.

Moss

Figure D.6. Astomum moss, image courtesy of Kiel Kietlinski.
Figure D.8. Amblystegium moss. Image courtesy of Hermann Schachner, Wikimedia Commons.

Figure D.8. Hedwigia moss. Image courtesy Bobby Hatatway, DiscoveryLife.
Appendix E. MSDS and Product Data Sheets
2365 Artillery Spores and More

Description
2365 Artillery Spores and More is a non-acid cleaner for the general maintenance and cleaning of EIFS surfaced buildings, aluminum and vinyl siding. 2365 is specially formulated to provide the extended dwell time to allow the removal of very tenacious biological growth like artillery spores as well as atmospheric soiling, auto and diesel exhaust, some oxidation stains and most organic growth.

Technical Data
<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance</td>
<td>Viscous off white liquid</td>
</tr>
<tr>
<td>Solubility</td>
<td>Complete</td>
</tr>
<tr>
<td>Flash Point</td>
<td>N/A</td>
</tr>
<tr>
<td>Odor</td>
<td>Faint citrus</td>
</tr>
<tr>
<td>Stability</td>
<td>Stable</td>
</tr>
<tr>
<td>pH</td>
<td>14</td>
</tr>
</tbody>
</table>

Preparation
Provide protection for foliage and pedestrian traffic. Test all surfaces which might be exposed to product for possible adverse reactions. Protect all surfaces and surrounding areas from possible damage which might occur from spillage or spray during usage.

All projects should start with a test application to determine the suitability of the cleaner, acceptable application method and dilution ratio if applicable. Test areas of at least 10 square feet are recommended and should involve the most severely contaminated condition. When possible, the test area should be left to dry in order to check for any latent reaction that might require a change in methods or products.

Application
2365 Artillery Spores and More may be applied by airless spray, synthetic fiber brush or roller. Brush agitation may be helpful on some projects. Dwell times may vary from five to thirty minutes. For removal of artillery spores dwell times of 1 1/2 to 2 hours may be needed. Do not allow the cleaner to dry on the surface. Removal of the cleaner and contamination can be accomplished with high pressure rinsing equipment. Care should be taken in the selection of the wand tip to avoid damage to the EIFS surface. In all cases, a thorough rinsing is required.

Limitations
ShoreBest™ 2365 Artillery Spores and More is for use by professional contractors only. Projects should not be undertaken when temperatures are below 50 degrees F. Do not allow the cleaner to dry on the surface. Misting of drying cleaner is permissible to avoid possible reapplication. Do not use on polished masonry.

Safety
All applicators must wear OSHA recommended protective equipment. Artillery Spores and More contains Potassium Hydroxide. Avoid contact with skin, eyes and clothing. Diluted and undiluted product can cause burns. Keep out of the reach of children. Do not ingest or inhale the cleaner, modify the cleaner with any material other than water or use the cleaner for any non-recommended purpose. Refer to the proper MSDS Sheet for treatment of persons exposed to or reacting to the cleaner.

Warranty

2917 Spruce Way • Pittsburgh, PA 15201 • (412) 471 – 3330 • infoproducts@shorebest.com
Shore Corporation warrants that this product conforms to the chemical composition described in the Product Label. SHORE CORPORATION EXPRESSLY DISCLAIMS ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. Shore Corporation shall not be responsible for any direct or consequential damages sustained as a result of the use of this product. Further, Shore Corporation shall not be liable for personal injuries, property damage or any other damages as a result of the use of this product, the sole responsibility of Shore Corporation under the within WARRANTY being the replacement of any nonconforming product. Acceptance and use of this product absolves Shore Corporation from any such liability whatsoever and from whatever source. The within WARRANTY may not be modified or extended by Shore Corporation representatives or distributors, neither of which are empowered to make any product representation inconsistent with the terms hereof.

**Customer Service**

Factory personnel can be contacted at 1-412-471-3330 for specific recommendations without any obligation.

Factory trained representatives are available in many locations to assist with project recommendations and dealer locations for purchase of materials. Call 1-412-471-3330 for the name and location of your nearest representative or dealer.

**END OF COPY**
MATERIAL SAFETY DATA SHEET

SECTION I  SUPPLIER INFORMATION

Common Name: ShoreBest™ 2365 Artillery Spores and More
Chemical Name: Shore Corporation
Formula: 2917 Spruce Way
Supplier: Pittsburgh, PA 15201
Phone: (412) 471-3330
Emergency Phone: Chem-Tel 1-800-255-3924 (24 hours)
Date Prepared: Monday, May 07, 2007
Edit Date: Wednesday, June 13, 2007

SECTION II  HAZARDOUS INGREDIENT INFORMATION

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>CAS Number</th>
<th>PEL-OSHA (ppm)</th>
<th>TWA-OSHA (mg/m³)</th>
<th>TLV-ACGIH (ppm)</th>
<th>STEL-ACGIH (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium Hydroxide</td>
<td>1310-58-3</td>
<td>2</td>
<td>2 (mg/m³)</td>
<td>2 (mg/m³)</td>
<td></td>
</tr>
<tr>
<td>Ethyl Alcohol</td>
<td>64-17-5</td>
<td>1000</td>
<td>1880</td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>Tetrapotassium Pyrophosphate</td>
<td>7320-34-5</td>
<td>5</td>
<td>5 (mg/m³)</td>
<td></td>
<td></td>
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</tbody>
</table>

SECTION III  PHYSICAL/CHEMICAL CHARACTERISTICS

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiling Point</td>
<td>212 °F</td>
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<tr>
<td>Specific Gravity</td>
<td>1.06</td>
</tr>
<tr>
<td>Melting Point</td>
<td>N/A °F</td>
</tr>
<tr>
<td>pH</td>
<td>14</td>
</tr>
<tr>
<td>Vapor Pressure (mm Hg)</td>
<td>N/A</td>
</tr>
<tr>
<td>Vapor Density (Air=1)</td>
<td>N/A</td>
</tr>
<tr>
<td>Evaporation Rate (Butyl Acetate =1)</td>
<td>N/A</td>
</tr>
<tr>
<td>Solubility in Water</td>
<td>Complete</td>
</tr>
<tr>
<td>Appearance and Odor</td>
<td>Viscous off white liquid with slight citrus odor</td>
</tr>
</tbody>
</table>

SECTION IV  FIRE AND EXPLOSION HAZARD DATA

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flash Point</td>
<td>Non °F</td>
</tr>
<tr>
<td>Auto-Ignition Temperature</td>
<td>N/A °F</td>
</tr>
<tr>
<td>LEL</td>
<td>N/A %</td>
</tr>
<tr>
<td>UEL</td>
<td>N/A %</td>
</tr>
<tr>
<td>Extinguisher Media</td>
<td>This material does not support combustion. Use CO₂, Dry Chemical, Foam Extinguisher or water spray</td>
</tr>
<tr>
<td>Special Fire Fighting Procedures:</td>
<td>Firefighters should wear NIOSH approved self-contained acid suits</td>
</tr>
<tr>
<td>Unusual Fire and Explosion Hazards:</td>
<td>None</td>
</tr>
</tbody>
</table>
SECTION V REACTIVITY DATA

Stability
Stable

Conditions and Materials to Avoid
Metals: Magnesium, aluminum, and Zinc; Some food sugars

Hazardous Decomposition or By-Products
Reactions with sugars may form Carbon Monoxide

Polymerization
Cannot Occur

Conditions to Avoid
None

SECTION VI HEALTH HAZARD DATA

Inhalation
Acute
Inhalation of mists can cause damage to the upper respiratory tract and to the lung tissue depending on extent of exposure. Effects range from mild irritation of mucous membranes, severe pneumonitis, and destruction of lung tissue.

Chronic
Not determined

Eye Contact
Acute
Causes severe burns, small quantities can result in permanent damage and/or loss of vision.

Chronic

Skin Contact
Acute
Corrosive action causes burns and frequently deep ulceration with subsequent scarring. Prolonged contact destroys tissue. Mist from solutions can cause irritant dermatitis.

Chronic

Ingestion
Acute
Ingestion can cause very serious damage to the mouth, esophagus, stomach, and other tissues with which contact is made. May be fatal.

Chronic

Medical Conditions Aggravated By Exposure
None known

Chemical Listed as Carcinogen or Potential Carcinogen
NO

National Toxicology Program
NO

I.A.R.C. Monographs :
NO

OSHA :
NO

ROUTES OF ENTRY/EMERGENCY AND FIRST AID PROCEDURES

Inhalation
Remove to fresh air. If breathing is difficult, administer oxygen. If breathing has stopped give artificial respiration. Keep person warm, quiet and get medical attention.

Eyes:
Rinse eyes with cool water for 15 minutes. Hold eyelids open during flushing with water. Get medical attention.

Skin:
Wash off with soap and water. If skin feels slippery, caustic may still be present in sufficient quantities to cause rash or burn. Continue washing until slick skin feeling is gone. Remove contaminated clothing. Launder contaminated clothing before reuse.

Ingestion:
Drink large quantities of water or acidic beverage ‘tomato or orange juice, carbonated soft drinks’. Do not induce vomiting. Take immediately to a hospital or physician
SECTION VII  PRECAUTIONS FOR SAFE HANDLING AND USE

Precautions To Be Taken In Handling and Storage: Store away from acids

Other Precautions : None

Steps To Be Taken In Case Material Is Released Or Spilled:
Large Spill: Persons not wearing protective equipment should be excluded from area of spill until clean-up has been completed. Stop spill at source, dike area of spill to prevent spreading, transfer to a salvage tank. Remaining material should be properly neutralized with dilute acid.
Small Spill: Neutralize with dilute acid or flush with large amounts of water.

Waste Disposal Method: Follow all Local, State, and Federal Regulations in your area

SECTION VIII  OTHER REGULATORY INFORMATION

SECTION 313 (With Chemicals Listed): This product contains the following toxic chemical(s) subject to the reporting requirements of Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA) and 40 CFR Part 372:

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>CAS Number</th>
<th>Weight Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>none</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

SECTION IX  SPECIAL PROTECTION & CONTROL MEASURES

RESPIRATORY PROTECTION: U.S. Bureau of Mines Respirator; self contained breathing device, airline or NIOSH approved respirator if other protective measures do not adequately control exposures to vapors.

The specific respirator selected must be based on contamination levels in the work place, must be based on the specific operation, must not exceed the working limits of the respirator, and must be jointly approved by the National Institute of Occupational Safety and Health and the Mine Safety and Health Administration (NIOSH-MSHA).

VENTILATION: Local Exhaust Mechanical Special Other

General room ventilation plus local exhaust at points of emission to keep vapor concentrations below applicable exposure limits.

Protective Gloves: Wear resistant gloves such as rubber or polyvinyl alcohol

Eye Protection: Chemical splash goggles or face shield.

Other Protective Clothing or Equipment: To prevent repeated or prolonged skin contact, wear impervious clothing and boots.

Work/Hygiene Practices : Keep off of clothing
SECTION X  DOT SHIPPING INFORMATION

DOT Shipping Name: Compounds, cleaning liquid
Label Requirements: None

<table>
<thead>
<tr>
<th>DOT Hazardous Substance</th>
<th>CAS Number</th>
<th>Reportable Quantity (RQ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium Hydroxide</td>
<td>1310-58-3</td>
<td>1000lbs.</td>
</tr>
<tr>
<td>Ethyl Alcohol</td>
<td>64-17-5</td>
<td>5000lbs.</td>
</tr>
</tbody>
</table>

The information presented herein is based on data considered to be accurate as of the date of preparation of this Material Safety Data Sheet. However, no warranty or representation, expressed or implied, is made as to the accuracy or completeness of the foregoing data and safety information. In addition, no responsibility can be assumed by vendor for any damage or injury resulting from abnormal use, from any failure to adhere to recommended practices, or from any hazards inherent in the nature of the product.
ShoreBest 2724 ASRSafe™ Concrete Cleaner is a highly effective non-acidic cleaner for horizontal masonry surfaces. 2724 can be successful in the removal of light to moderate atmospheric soiling, most grease and oil deposits, rubber heel marks, food and biological stains, and certain other surface deposits. Unlike many other concrete cleaners this product has been formulated to be aggressive towards soiling but not contribute to Alkali Silica Reaction (ASR) in sensitive concrete.

**Preparation**
Provide protection for foliage and pedestrian traffic. Test non-masonry surfaces for any possible adverse reactions. Protect all surfaces and situations where damage might occur during usage.

All projects should start with a test application to determine the suitability of the cleaner, acceptable application method and dilution ratio. Test areas of at least ten square feet are recommended and should involve the most severely contaminated condition.

**Application**
ShoreBest 2724 ASRSafe™ Concrete Cleaner is most effective when applied by low-pressure spray. Brush application and agitation may prove helpful on some surfaces. Dwell times may vary from five to thirty minutes. Removal of the cleaner and contaminant can be accomplished most successfully with a pressure washer. A thorough rinsing is required. Dilution ratios are from 0 to 5 parts water depending upon conditions. This product can be used in automatic concrete scrubbing machines.

**Safety**
All applicators must wear OSHA recommended protective equipment. ShoreBest 2724 ASRSafe™ Concrete Cleaner contains Potassium Hydroxide. Avoid contact with skin, eyes and clothing. Undiluted product can cause severe irritation and burns.

**First Aid**
Inhalation: Remove to fresh air. If breathing is difficult, administer oxygen. If breathing has stopped give artificial respiration. Keep person warm, quiet and get medical attention.

Eyes: Rinse eyes with cool water for 15 minutes. Hold eyelids open during flushing with water. Get medical attention.
Skin Contact: Wash off with soap and water. If skin feels slippery, caustic may still be present in sufficient quantities to cause rash or burn. Continue washing until slick skin feeling is gone. Remove contaminated clothing. Launder contaminated clothing before reuse.

Ingestion: Drink large quantities of water or acidic beverage ‘tomato or orange juice, carbonated soft drinks’. Do not induce vomiting. Take immediately to a hospital or physician.

Compound cleaning liquid (contains potassium hydroxide) NA – 1760
MATERIAL SAFETY DATA SHEET

SECTION I  SUPPLIER INFORMATION

Common Name: ShoreBest™ 2724 ASRSafe Concrete Cleaner
Chemical Name: Shore Corporation
Formula: 2917 Spruce Way
Supplier: Pittsburgh, PA 15201
Phone: (412) 471-3330
Emergency Phone: Chem-Tel 1-800-255-3924 (24 hours)
Date Prepared: February 8, 2013
Edit Date: February 8, 2013

SECTION II  HAZARDOUS INGREDIENT INFORMATION

CFR 29 Part 1910.1000 Table Z-1 (February 28, 2006 issue)

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>CAS Number</th>
<th>PEL-OSHA (ppm)</th>
<th>TWA-OSHA (mg/m³)</th>
<th>TLV-ACGIH (ppm)</th>
<th>STEL-ACGIH (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium Hydroxide</td>
<td>1310-58-3</td>
<td></td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

SECTION III  PHYSICAL/CHEMICAL CHARACTERISTICS

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiling Point:</td>
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<tr>
<td>Specific Gravity:</td>
<td>1.07</td>
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<tr>
<td>Melting Point:</td>
<td>N/A °F</td>
</tr>
<tr>
<td>pH:</td>
<td>14</td>
</tr>
<tr>
<td>Vapor Pressure (mm Hg):</td>
<td>N/A</td>
</tr>
<tr>
<td>Vapor Density (Air=1):</td>
<td>N/A</td>
</tr>
<tr>
<td>Evaporation Rate (Butyl Acetate =1):</td>
<td>N/A</td>
</tr>
<tr>
<td>Solubility in Water:</td>
<td>Complete</td>
</tr>
<tr>
<td>Appearance and Odor:</td>
<td>Light gold liquid with a mild odor</td>
</tr>
</tbody>
</table>

SECTION IV  FIRE AND EXPLOSION HAZARD DATA

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flash Point:</td>
<td>None °F</td>
</tr>
<tr>
<td>Auto-Ignition Temperature:</td>
<td>N/A °F</td>
</tr>
<tr>
<td>LEL:</td>
<td>N/A %</td>
</tr>
<tr>
<td>UEL:</td>
<td>N/A %</td>
</tr>
<tr>
<td>Extinguisher Media:</td>
<td>This material does not support combustion. Use CO₂, Dry Chemical, Foam Extinguisher or water spray</td>
</tr>
<tr>
<td>Special Fire Fighting Procedures:</td>
<td>Firefighters should wear NIOSH approved self-contained acid suits</td>
</tr>
<tr>
<td>Unusual Fire and Explosion Hazards:</td>
<td>None</td>
</tr>
</tbody>
</table>
SECTION V  REACTIVITY DATA

<table>
<thead>
<tr>
<th>Stability</th>
<th>Stable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conditions and Materials to Avoid</td>
<td>Metals: Magnesium, aluminum, and Zinc; Some food sugars</td>
</tr>
<tr>
<td>Hazardous Decomposition or By-Products</td>
<td>Reactions with sugars may form Carbon Monoxide</td>
</tr>
<tr>
<td>Polymerization</td>
<td>Cannot Occur</td>
</tr>
<tr>
<td>Conditions to Avoid</td>
<td>None</td>
</tr>
</tbody>
</table>

SECTION VI  HEALTH HAZARD DATA

Inhalation
Acute: Inhalation of mists can cause damage to the upper respiratory tract and to the lung tissue depending on extent of exposure. Effects range from mild irritation of mucous membranes, severe pneumonitis, and destruction of lung tissue.
Chronic: Not determined

Eye Contact
Acute: Causes severe burns, small quantities can result in permanent damage and/or loss of vision.
Chronic: 

Skin Contact
Acute: Prolonged contact destroys tissue. Mist from solutions can cause irritant dermatitis.
Chronic: 

Ingestion
Acute: Ingestion can cause very serious damage to the mouth, esophagus, stomach, and other tissues with which contact is made. May be fatal.
Chronic: 

Medical Conditions Aggravated By Exposure: None known
Chemical Listed as Carcinogen or Potential Carcinogen: NO
National Toxicology Program: NO
I.A.R.C. Monographs: NO
OSHA: NO

ROUTES OF ENTRY/EMERGENCY AND FIRST AID PROCEDURES

Inhalation: Remove to fresh air. If breathing is difficult, administer oxygen. If breathing has stopped give artificial respiration. Keep person warm, quiet and get medical attention.

Eyes: Rinse eyes with cool water for 15 minutes. Hold eyelids open during flushing with water. Get medical attention.

Skin: Wash off with soap and water. If skin feels slippery, caustic may still be present in sufficient quantities to cause rash or burn. Continue washing until slick skin feeling is gone. Remove contaminated clothing. Launder contaminated clothing before reuse.

Ingestion: Drink large quantities of water or acidic beverage ‘tomato or orange juice, carbonated soft drinks’. Do not induce vomiting. Take immediately to a hospital or physician.
SECTION VII  PRECAUTIONS FOR SAFE HANDLING AND USE

Precautions To Be Taken In Handling and Storage: Store away from acids

Other Precautions: None

Steps To Be Taken In Case Material Is Released Or Spilled:
Large Spill: Persons not wearing protective equipment should be excluded from area of spill until clean-up has been completed. Stop spill at source, dike area of spill to prevent spreading, transfer to a salvage tank. Remaining material should be properly neutralized with dilute acid.
Small Spill: Neutralize with dilute acid or flush with large amounts of water.

Waste Disposal Method: Follow all Local, State, and Federal Regulations in your area

SECTION VIII  OTHER REGULATORY INFORMATION

SECTION 313 (With Chemicals Listed): This product contains the following toxic chemical(s) subject to the reporting requirements of Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA) and 40 CFR Part 372:

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>CAS Number</th>
<th>Weight Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>none</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

SECTION IX  SPECIAL PROTECTION & CONTROL MEASURES

RESPIRATORY PROTECTION: U.S. Bureau of Mines Respirator; self contained breathing device, airline or NIOSH approved respirator if other protective measures do not adequately control exposures to vapors.

The specific respirator selected must be based on contamination levels in the work place, must be based on the specific operation, must not exceed the working limits of the respirator, and must be jointly approved by the National Institute of Occupational Safety and Health and the Mine Safety and Health Administration (NIOSH-MSHA).

VENTILATION:

<table>
<thead>
<tr>
<th>Local Exhaust</th>
<th>Mechanical</th>
<th>Special</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>xxx</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

General room ventilation plus local exhaust at points of emission to keep vapor concentrations below applicable exposure limits.

Protective Gloves: Wear resistant gloves such as rubber or polyvinyl alcohol

Eye Protection: Chemical splash goggles or face shield.

Other Protective Clothing or Equipment: To prevent repeated or prolonged skin contact, wear impervious clothing and boots.

Work/Hygiene Practices: Keep off of clothing
SECTION X  DOT SHIPPING INFORMATION

DOT Shipping Name: NA – 1760 Compound Cleaning Liquid (Contains Potassium Hydroxide) , 8, PGIII
Label Requirements: CORROSIVE

<table>
<thead>
<tr>
<th>DOT Hazardous Substance</th>
<th>CAS Number</th>
<th>Reportable Quantity (RQ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium Hydroxide</td>
<td>1310-58-3</td>
<td>1000lbs.</td>
</tr>
</tbody>
</table>

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**DIRECTIONS FOR USE**

It is a violation of Federal law to use this product in a manner inconsistent with its labeling. Wear protective eyewear (goggles or face shield), gloves, and protective clothing when using this product. Dry treated areas and articles such as clothing before use. Remove children and pets from treated area until completely dry. Clean surfaces prior to application.

**Approved Commercial and Industrial Uses:** This product can be applied to organic or inorganic substrates by brushing, dipping, padding, soaking, spraying, or by using foam finishing techniques. Use areas include air filters/materials, bed sheets, blankets, bedspreads, carpets and draperies, mattress pads and ticking, shower curtains, outerwear apparel (jackets, sweaters, sweatshirts, coats, raincoats, overcoats, jerseys, ponchos), athletic and casual shoes. See attached pages for additional approved commercial and industrial uses.

**Approved Residential Uses:** Washable walls, floors, carpeting, tubs, vanity tops, window sills, appliances, plastic, vinyl, mattress pads and mattress ticking, underwear, toweling, hosiery. See attached pages for additional approved residential uses and application methods.

**STORAGE AND DISPOSAL**

Do not contaminate water, food, or feed by storage and disposal. **Pesticide Storage:** Store in original, tightly closed containers below 30°C (86°F) and above 0°C (32°F) in a secure area inaccessible to children and away from food or feed. **Pesticide Disposal:** Residential use - Wastes resulting from the use of this product may be disposed of on site. Commercial/Industrial Use - Wastes resulting from the use of this product may be disposed of on site or at an approved waste disposal facility. **Container Disposal:** Residential use - Securely wrap original container in several layers of newspaper and discard in trash. Commercial use - Triple rinse (or equivalent) Then offer for recycling or reconditioning, or puncture and dispose of in a sanitary landfill or by other procedures approved by state and local authorities.

---

**ENVIROSYSTEMS® BioShield® 75**

**MICROBIOSTATIC AGENT***

**Active Ingredients:**

Octadecylaminodimethyltriethoxysilyl propyl ammonium chloride: ....................... 0.75%  
Other Ingredients:.......................... 99.25%  
TOTAL .................................. 100.00%

*A microbiostatic agent is an agent that inhibits the growth of odor causing bacteria and fungi (mold and mildew), bacteria and fungi (mold and mildew) which cause staining and discoloration, and algae. This product does not protect users or others against food-borne or disease causing bacteria or fungi.

Do not use in any application involving direct or indirect food or drinking water contact.

**KEEP OUT OF REACH OF CHILDREN CAUTION**

See side panels for additional precautionary statements.

**EPA Reg. No. 53053-7**  
**EPA Est. No. 53053-NC-01**  
**Manufactured by: INDUSCO, LTD.**  
**2319 Joe Brown Drive**  
**Greensboro, NC 27405**  
**(336) 375-7555 FAX (336) 375-0826**

---

**PRECAUTIONARY STATEMENTS**

**HAZARDS TO HUMANS AND DOMESTIC ANIMALS**

**CAUTION:** Causes moderate eye irritation. Avoid contact with skin, eyes and clothing. Harmful if inhaled or absorbed through the skin. Avoid breathing vapors or spray mist. Wear protective eyewear and protective clothing. Wash thoroughly with soap and water after handling and before eating, drinking, chewing gum or using the toilet. Remove contaminated clothing and wash before reuse.

**ENVIRONMENTAL HAZARDS**

**Commercial and industrial uses:** This pesticide is toxic to fish. Do not discharge effluent containing this product into lakes, streams, ponds, estuaries, oceans, or other waters unless in accordance with the requirements of a National Pollutant Discharge Elimination System (NPDES) permit and the permitting authority has been notified in writing prior to discharge. Do not discharge effluent containing this product to sewer systems without previously notifying the local sewage treatment plant authority. For guidance, contact your State Water Board or Regional Office of the EPA.

De-activation required during clean up if a spill occurs. De-activation of this product can be achieved by the addition of anionic surfactant (such as soap, sulfonates, sulfates) in quantity equivalent to that of this product.

**Residential use:** This pesticide is toxic to fish. Do not contaminate water by cleaning of equipment or disposal of pesticide. Do not apply directly to water.

**FIRST AID**

Have the product container or label with you when calling the poison control center or doctor, or going for treatment.

**IF ON SKIN:** Take off contaminated clothing. Rinse skin immediately with plenty of water for 15-20 minutes. Call a poison control center or doctor for treatment advice.

**IF INHALED:** Move person to fresh air. If person is not breathing, call 911 or an ambulance, then give artificial respiration, preferably mouth-to-mouth, if possible. Call a poison control center or doctor for further treatment advice.

**IF IN EYES:** Hold eye open and rinse slowly and gently with water for 15-20 minutes. Remove contact lenses, if present, after the first 5 minutes, then continue rinsing. Call poison control center or doctor for treatment advice.

**IF SWALLOWED:** Call a poison control center or doctor immediately for treatment advice. Have person sip a glass of water if able to swallow. Do not induce vomiting unless told to do so by a poison control center or doctor. Do not give anything by mouth to an unconscious person.

ESL082008 REV091808
EnviroSystems® BioShield® 75 creates an invisible barrier to inhibit the growth of odor causing bacteria, bacteria and fungi (mold and mildew) which cause staining and discoloration, and algae.

DIRECTIONS FOR USE

Approved commercial and industrial applications

It is a violation of Federal law to use this product in a manner inconsistent with its labeling. Wear protective eyewear (goggles or face shield) and gloves when using this product. Dry treated areas and articles such as clothing before use. Remove children and pets from treated area until completely dry.

EnviroSystems® BioShield® 75 can be applied to organic or inorganic substrates by brushing, dipping, padding, soaking, spraying or by using foam finishing techniques.

The substrate can be dried at temperatures from ambient to a maximum of 160°C (320°F) to effect complete condensation of silanol groups and to remove water, solvents and/or traces of methanol from hydrolysis. Optimum application and drying conditions, such as time and temperature, should be determined for each application before use. If necessary, reapply EnviroSystems® BioShield® 75 every three months or when odor, staining and discoloration due to bacteria, mold stains, mildew stains, and algae stains return.

Approved commercial and industrial applications

The active ingredient in EnviroSystems® BioShield® 75 is effective against odor causing bacteria and fungi (mold and mildew), bacteria and fungi (mold and mildew) which cause staining and discoloration, and algae as a static agent. EnviroSystems® BioShield® 75 can be used as a final bacteriostatic finish on the following items to impart bacteriostatic/fungistatic (mold and mildew) and algaestatic activity.

- Air filters for furnaces, air-conditioners, air purification devices, automobiles, recirculating air handling systems
- Air filters/materials
- Aquarium filter material
- Bed sheets, blankets, and bedspreads
- Buffer pads (abrasive and polishing)
- Carpets and draperies
- Fiberfill for upholstery, sleeping bags, apparel, where the fiber is cotton, natural down, nylon, polyester, rayon, or wool
- Fiberglass ductboard
- Fire hose fabric
- Humidifier belts
- Mattress pads and ticking
- Men's underwear and outerwear
- Non-woven polyester
- Outerwear apparel (jackets, sweaters, sweatshirts, coats, raincoats, overcoats, jerseys, ponchos)
- Polyurethane and cellulose foam for household, industrial, and institutional mops
- Polyurethane and polyethylene foam, when covered
Polyurethane foam for packaging and cushioning in non-food contact applications
Polyurethane foam used as a growth medium for non-food crops and plants
Roofing materials - defined as shingles, roofing granules, wood shakes, felt, stone and synthetic overcoats
Sand bags, tents, tarpaulins, sails, and ropes
Athletic and casual shoes
Shoe insoles
Shower curtains
Socks comprised of nylon, nylon/orlon, cotton/nylon, linen/Lycra, acrylic/polypropylene/nylon/Lycra, wool/silk/nylon/Lycra and wool/acrylic/nylon/Lycra
Throw rugs
Toweling made of 100 percent cotton, 100 percent polyester, and blends of the two fibers
Toilet tank and seat covers
Umbrellas
Upholstery made of acetates, acrylics, cotton, fiberglass, nylon, polyester, polyethylene, polyolefins, polypropylene, rayon, spandex, vinyl, wool
Vacuum cleaner bags and filters
Vinyl paper-wallpaper for non-food contact surfaces
Disposable wiping cloths that can be used for multiple purposes such as dusting or washing furniture, cars, walls, windows, floors, appliances, counter tops; the wiping cloths do not impart pesticide properties
Women’s hosiery
Women’s intimate apparel

DIRECTIONS FOR USE
Approved commercial applications in homes, offices, automobiles and the following institutions: schools, hospitals, daycare centers, churches, correctional facilities

It is a violation of Federal law to use this product in a manner inconsistent with its labeling. Wear protective eyewear (goggles or face shield) and gloves when using this product. Dry treated areas and articles such as clothing before use. Remove children and pets from treated area until completely dry. Clean surfaces prior to application.

The active ingredient in EnviroSystems® BioShield® 75 is effective against odor causing bacteria and fungi (mold and mildew), bacteria and fungi (mold and mildew) which cause staining and discoloration, and algae as a static agent. EnviroSystems® BioShield® 75 can be used as a final bacteriostatic finish on the following items to impart bacteriostatic/fungistatic (mold and mildew) and algaeastatic activity.

- Air filters for furnaces, air-conditioners, air purification devices, automobiles, recirculating air handling systems
- Air filters/materials
- Aquarium filter material
- Bed sheets, blankets, and bedspreads
- Buffer pads (abrasive and polishing)
- Carpets and draperies
- Fiberfill for upholstery, sleeping bags, apparel, where the fiber is cotton, natural down, nylon, polyester, rayon, or wool
- Fiberglass ductboard
- Fire hose fabric
- Humidifier belts
- Mattress pads and ticking
Men's underwear and outerwear
Non-woven polyester
Outerwear apparel (jackets, sweaters, sweatshirts, coats, raincoats, overcoats, jerseys, ponchos)
Polyurethane and cellulose foam for household, industrial, and institutional mops
Polyurethane and polyethylene foam, when covered
Polyurethane foam for packaging and cushioning in non-food contact applications
Polyurethane foam used as a growth medium for non-food crops and plants
Roofing materials - defined as shingles, roofing granules, wood shakes, felt, stone and synthetic overcoats
Sand bags, tents, tarpaulins, sails, and ropes
Athletic and casual shoes
Shoe insoles
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Throw rugs
Toweling made of 100 percent cotton, 100 percent polyester, and blends of the two fibers
Toilet tank and seat covers
Umbrellas
Upholstery made of acetates, acrylics, cotton, fiberglass, nylon, polyester, polyethylene, polyolefins, polypropylene, rayon, spandex, vinyl, wool
Vacuum cleaner bags and filters
Vinyl paper-wallpaper for non-food contact surfaces
Disposable wiping cloths that can be used for multiple purposes such as dusting or washing furniture, cars, walls, windows, floors, appliances, counter tops; the wiping cloths do not impart pesticide properties
Women’s hosiery
Women’s intimate apparel

For Pump Spray Application: Using pump sprayer, spray entire area 4”- 6” from the surface making sure the surface is completely covered. Apply and then let stand until dry or let stand 3 minutes and wipe dry with cloth or sponge. If spotting occurs, wipe with moist cloth or sponge. Test for staining and color-fastness of fabrics and carpets by treating and drying a small, concealed area prior to application. One gallon of EnviroSystems® BioShield® 75 treats approximately 200 square feet. When treating coarser substrates, more EnviroSystems® BioShield® 75 may be required due to absorption. A fan may be used to assist in drying carpeting.

For Commercial Spray Application: For commercial application equipment (i.e., carpet/upholstery steamers, rotary jet extraction cleaners, pressure sprayers) apply and then let stand until dry or let stand 3 minutes and wipe dry with cloth or sponge. If spotting occurs, wipe with moist cloth or sponge. Test for staining and color-fastness of fabrics and carpets by treating and drying a small, concealed area prior to application. One gallon of EnviroSystems® BioShield® 75 treats approximately 200 square feet. When treating coarser substrates, more EnviroSystems® BioShield® 75 may be required due to absorption. Dry carpet areas and surfaces before re-entry and dry articles before use. A fan may be used to assist in drying carpeting.

For Dipping/Soaking Application: Use appropriate sized wash basin or tub for dipping/soaking the item you are treating. Use enough EnviroSystems® BioShield® 75 to completely submerge item. Completely submerge item in solution for 3 minutes. Remove item and dry. Test for staining and color-fastness of fabrics by treating and drying a small, concealed area prior to application. Do not reuse solution after dipping/soaking.

The substrate can be dried at room temperatures or at temperatures to a maximum of 160° C (320° F), for example in a clothes dryer. Remove excess liquid before attempting to dry in a clothes dryer. If necessary, reapply EnviroSystems® BioShield® 75 every three months or when odor, staining and discoloration due to bacteria, mold stains, mildew stains, and algae stains return.
**DIRECTIONS FOR USE**  
**For residential applications**

It is a violation of Federal law to use this product in a manner inconsistent with its labeling. Wear protective eyewear (goggles or face shield) and gloves and protective clothing when using this product. Dry treated areas and articles such as clothing before use. Remove children and pets from treated area until completely dry. Clean surfaces prior to application.

**Approved residential uses**

The active ingredient in EnviroSystems® BioShield® 75 is effective against odor causing bacteria, bacteria which cause staining and discoloration, fungi (mold and mildew) and algae as a static agent.

<table>
<thead>
<tr>
<th>Pest controlled</th>
<th>Method of Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bedsheets, blankets, bedspreads, curtains, draperies (washable only), underwear, socks, intimate apparel, hosiery, throw rugs, toweling, toilet tank covers, shower curtains, shoe insoles, outerwear apparel (jackets, sweaters, sweatshirts, coats, raincoats, overcoats, jerseys, ponchos). EnviroSystems® BioShield® 75 can be applied to fabrics made of acetates, acrylics, cotton, fiberglass, linen, Lycra, nylon, orlon, polyester, polyethylene, polyolefins, polypropylene, rayon, silk, spandex, vinyl, and wool. Odor causing bacteria, bacteria which cause staining and discoloration, and fungi (mold and mildew)</td>
<td><strong>DIP/SOAK:</strong> Use appropriate sized wash basin or tub for dipping/soaking the item you are treating. Use enough EnviroSystems® BioShield® 75 to completely submerge item. Keep item in solution for 3 minutes. Remove item and wring excess liquid. Drying may be attained by dripping dry or wringing excess liquid from treated item. For larger items (e.g., bedspreads, curtains, draperies), place in washing machine on spin cycle to aid in the removal of excess liquid. Test staining and color-fastness of fabric and carpets by treating and drying a small concealed area prior to application. Do not reuse solution after dipping/soaking. Dry treated articles before use. Substrates can be hang-dried at room temperature or at temperatures to a maximum of 160 °C (320 °F); (for example in a clothes dryer). Remove excess liquid before attempting to dry in a clothes dryer. If necessary, reapply EnviroSystems® BioShield® 75 every three months or when odor, staining and discoloration due to bacteria, mold stains, and mildew stains return.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pest controlled</th>
<th>Method of Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air filters and air filter material for • Furnaces, air conditioners • Air purification systems • Automobiles • Recirculating air handling systems • Vacuum cleaner filters • Aquariums Odor causing bacteria, bacteria which cause staining and discoloration, fungi (mold and mildew), and algae</td>
<td><strong>SPRAY:</strong> Clean surface prior to application. Using a trigger pump sprayer or pressure sprayer, spray the entire surface area 4”-6” from the surface making sure the surface is completely covered. Let stand until dry or let stand 3 minutes and wipe dry with cloth or sponge. If spotting occurs, wipe with moist cloth or sponge. Test staining and color-fastness of fabric by treating and drying a small concealed area prior to application. If necessary, reapply EnviroSystems® BioShield® 75 every three months or when odor, staining and discoloration due to bacteria, mold stains, and mildew stains return. <strong>SPRAY:</strong> When treating filters, remove filter from the unit. Using a trigger pump sprayer or pressure sprayer, spray the entire surface area 4”- 6” from the surface making sure the surface is completely covered. Apply and then let stand until dry. If necessary, reapply EnviroSystems® BioShield® 75 every three months or when odor, staining and discoloration due to bacteria, mold stains, mildew stains, and algae stains return.</td>
</tr>
<tr>
<td>Pest controlled</td>
<td>Method of Application</td>
</tr>
<tr>
<td>-----------------</td>
<td>----------------------</td>
</tr>
<tr>
<td><strong>Carpeting</strong></td>
<td><strong>SPRAY:</strong> Apply to clean carpet surface. Using a trigger pump sprayer or pressure sprayer, spray the entire surface area 4”- 6” from the surface making sure the surface is completely covered. For rotary jet extraction cleaners and carpet steamers, add EnviroSystems® BioShield® 75 directly to the cleaning tank, then operate the equipment in accordance with manufacturer’s instructions. Apply and then let stand until dry. Test staining and color-fastness of carpets by treating and drying a small concealed area prior to application. EnviroSystems® BioShield® 75 treats approximately 200 square feet per gallon (50 square feet per quart). When treating coarser substrates (e.g., wool carpeting), more EnviroSystems® BioShield® 75 may be required due to absorption. Dry carpet areas and surfaces before re-entry. A fan may be used to assist in drying carpeting. Remove children and pets from treated area until completely dried. If necessary, reapply EnviroSystems® BioShield® 75 every three months or when odor, staining and discoloration due to bacteria, mold stains, and mildew stains return.</td>
</tr>
<tr>
<td>Odor causing bacteria, bacteria which cause staining and discoloration, and fungi (mold and mildew)</td>
<td><strong>Mattress pad and mattress ticking and upholstery composed of acetates, acrylcs, cotton, fiberglass, nylon, polyester, polyethylene, polyolefins, polypropylene, rayon, spandex, vinyl, wool; fiberfill to be used in upholstery, sleeping bags, apparel, where the fiber is cotton, natural down, nylon, rayon or wool</strong></td>
</tr>
<tr>
<td>Odor causing bacteria, bacteria which cause staining and discoloration, and fungi (mold and mildew)</td>
<td><strong>Tents, tarpaulins, sails, ropes</strong></td>
</tr>
<tr>
<td>Odor causing bacteria, bacteria which cause staining and discoloration, fungi (mold and mildew), and algae</td>
<td><strong>Roofing materials (such as shingles, roofing granules, wood shakes, felt, stone, synthetic overcoats)</strong></td>
</tr>
<tr>
<td>Odor causing bacteria, bacteria which cause staining and discoloration, fungi (mold and mildew), and algae</td>
<td><strong>DIP/SOAK:</strong> Use appropriate sized wash basin or tub for dipping/soaking the item you are treating. Use enough EnviroSystems® BioShield® 75 to completely submerge item. Keep item in solution for three minutes. Remove item and wring excess liquid. Do not reuse solution after dipping/soaking. Dry treated articles before use. Substrates can be hang-dried at room temperature or at temperatures to a maximum of 160 °C (320 °F); (for example in a clothes dryer). Remove excess liquid before attempting to dry in a clothes dryer. If necessary, reapply EnviroSystems® BioShield® 75 every three months or when odor, staining and discoloration due to bacteria, mold stains, mildew stains, and algae stains return.</td>
</tr>
<tr>
<td>Pest controlled</td>
<td>Method of Application</td>
</tr>
<tr>
<td>------------------------------------------------------</td>
<td>------------------------------------------------------------</td>
</tr>
<tr>
<td>Buffer pads (polishing and abrasive), Polyurethane and cellulose foam for household mops, vacuum cleaner bags, umbrellas, casual shoes, athletic shoes</td>
<td>Odor causing bacteria, bacteria which cause staining and discoloration, and fungi (mold and mildew)</td>
</tr>
<tr>
<td></td>
<td><strong>SPRAY</strong>: Clean surface prior to application. Using a trigger pump sprayer or pressure sprayer, spray the entire surface area 4”-6” from the surface making sure the surface is completely covered. Let stand until dry or let stand 3 minutes and wipe dry with cloth or sponge. If spotting occurs, wipe with moist cloth or sponge. If necessary, reapply EnviroSystems® BioShield® 75 every three months or when odor, staining and discoloration due to bacteria, mold stains, and mildew stains return.</td>
</tr>
<tr>
<td>Tubs, glazed tiles, vanity tops, shower curtains, shower stalls (areas), sinks, washable walls, wall paper for non-food contact, floors, window sills, cabinets, garbage cans, appliances, refrigerators (exterior), fiberglass, formica, glazed tiles, glazed porcelain, synthetic marble, plastic, vinyl</td>
<td>Odor causing bacteria, bacteria which cause staining and discoloration, and fungi (mold and mildew)</td>
</tr>
<tr>
<td></td>
<td><strong>SPRAY</strong>: Using a trigger pump sprayer, spray the entire surface area 4”- 6” from the surface making sure the surface is completely covered. Let stand until dry or let stand 3 minutes and wipe dry with cloth or sponge. If spotting occurs, wipe with moist cloth or sponge. If necessary, reapply EnviroSystems® BioShield® 75 every three months or when odor, staining and discoloration due to bacteria, mold stains, and mildew stains return.</td>
</tr>
</tbody>
</table>

**STORAGE AND DISPOSAL**

Do not contaminate water, food, or feed by storage and disposal.

Pesticide Storage: Store in original, tightly closed containers below 30°C (86°F) and above 0°C (32°F) in a secure area inaccessible to children and away from food or feed.

Pesticide Disposal: Residential Use - Wastes resulting from the use of this product may be disposed of on site. Commercial/industrial Use - Wastes resulting from the use of this product may be disposed of on site or at an approved waste disposal facility.

Container Disposal: Residential Use - Securely wrap original container in several layers of newspaper and discard in trash. Commercial/industrial Use - Triple rinse (or equivalent). Then offer for recycling or reconditioning, or puncture and dispose of in a sanitary landfill, or incineration, or, if allowed by state and local authorities, by burning. If burned, stay out of smoke.

FOR MORE INFORMATION CONCERNING THIS PRODUCT, PLEASE CONSULT THE MATERIAL SAFETY DATA SHEET (MSDS). THE MSDS CAN BE OBTAINED BY CONTACTING INDUSCO, LTD. AT 2319 JOE BROWN DRIVE, GREENSBORO, NC, 27405, (336) 375-7555.

IMPORTANT: WARRANTY AND DISCLAIMER INFORMATION

IndusCo, Ltd., warrants that the product conforms to its chemical description and is reasonably fit for the purposes stated in this bulletin when used in accordance with directions under normal conditions of use; but this warranty of fitness for a particular purpose does not extend to the use of this product contrary to bulletin instructions, or under abnormal conditions, or under conditions not reasonably foreseeable to the seller, and buyer assumes the risk of any such use. INDUSCO, LTD. SPECIFICALLY DISCLAIMS ANY OTHER EXPRESS OR IMPLIED WARRANTY, INCLUDING THE WARRANTY OF MERCHANTABILITY.

Sold by: **INDUSCO, LTD.**
2319 Joe Brown Drive, Greensboro, NC 27405
(336) 375-7555  FAX (336) 375-0826

ESL082008  REV091808
MATERIAL SAFETY DATA SHEET

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME: Envirosystems® BioShield® 75
CHEMICAL DESCRIPTION: Organosilane
COMPANY IDENTIFICATION: IndusCo, Ltd.
2319 Joe Brown Drive
Greensboro, NC 27405
EMERGENCY TELEPHONE (800) 262-8200 (24 HOURS) CHEMTREC

2. COMPOSITION/ INFORMATION ON INGREDIENTS

Our hazard evaluation has identified the following chemical substance(s) as hazardous. Consult Section 15 for the nature of the hazard(s).

<table>
<thead>
<tr>
<th>Hazardous Substance(s)</th>
<th>CAS NO.</th>
<th>% Weight</th>
<th>OSHA (PEL)</th>
<th>ACGIH (TLV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Octadecylaminodimethyltrihydroxysilyl propyl</td>
<td>27668-52-6</td>
<td>0.75%</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>ammonium chloride</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SECTION 2 NOTES: None

The above information is not intended for use in preparing product specifications.

3. HAZARDS IDENTIFICATION

HMIS Profile: Health 1 Flammability 0 Physical Hazard 0 Personal Protection D

** EMERGENCY OVERVIEW **

Warning: SLIGHTLY IRRITATING TO THE EYES. HARMFUL IF INGESTED OR INHALED.

Do not get in eyes or on clothing. Avoid contact with skin or clothing, and avoid breathing vapor. Wear protective eyewear (goggles or face shield). Wash thoroughly with soap and water after handling. Remove contaminated clothing and wash clothing before use.

PRIMARY ROUTES OF ENTRY: skin contact, ingestion, and eye contact.

POTENTIAL HEALTH EFFECTS:

EYES: Slightly irritating to the eyes.

SKIN: May cause slight irritation.

INGESTION: Harmful if swallowed.

INHALATION: Harmful if inhaled.

MEDICAL CONDITIONS GENERALLY AGGRAVATED BY EXPOSURE: Not known.

CARCINOGENS:
OSHA: No ACGIH: No NTP: No IARC: No

SECTION 3 NOTES: none

4. FIRST AID MEASURES

EYES: Hold eye open and flush with a steady, gentle stream of water for 15-20 minutes. If present, remove contact lenses after the first 5 minutes, then continue rinsing. Call a poison control center or doctor for treatment advice.

SKIN: Take off contaminated clothing. Rinse skin immediately with plenty of water for 15-20 minutes. Call a poison control center or doctor for treatment advice.

INGESTION: Call a poison control center or doctor immediately for treatment advice. Have the person sip a glass of water if able to swallow. Do not induce vomiting unless told to do so by a poison control center or doctor. Do not give anything by mouth to an unconscious person.

INHALATION: Move person to fresh air. If not breathing, give artificial respiration. Seek medical attention.

5. FIRE FIGHTING MEASURES

FLAMMABLE LIMITS IN AIR:

<table>
<thead>
<tr>
<th></th>
<th>UPPER</th>
<th>LOWER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

EXTINGUISHING MEDIA:
N/A

SPECIAL FIRE FIGHTING PROCEDURES:
N/A

UNUSUAL FIRE AND EXPLOSION HAZARDS:
N/A

HAZARDOUS DECOMPOSITION PRODUCTS:
N/A

Section 5 Notes: None.

6. ACCIDENTAL RELEASE MEASURES

ACCIDENTAL RELEASE MEASURES:

For small spills, hose away with water.
For large spills, transfer to suitable container for disposal.

SECTION 6 NOTES: This material will be slippery if spilled.

7. HANDLING AND STORAGE
HANDLING AND STORAGE: Do not get into eyes. For sensitive skin, wear gloves (rubber/latex) when handling product. Store away from heat and direct sunlight.

SECTION 7 NOTES: None.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

EYE PROTECTION: To avoid eye contact, wear goggles.
SKIN PROTECTION: Rubber/Latex gloves for sensitive skin.
OTHER PROTECTIVE CLOTHING OR EQUIPMENT: None

SECTION 8 NOTES: None

9. PHYSICAL AND CHEMICAL PROPERTIES

PHYSICAL STATE: Liquid
APPEARANCE: Clear colorless liquid
ODOR: Odorless
SPECIFIC GRAVITY: 0.98 – 1.02
SOLUBILITY IN WATER: Complete
pH: 5.17
FREEZING POINT: 32 °F/0 °C
BOILING POINT: 212 °F/100 °C
MELTING POINT: Not available
VAPOR PRESSURE: Not available
VISCOSITY: <85.5 mPa·s
VOLATILE CONTENT: Not available
PERCENT SOLIDS BY WEIGHT: Not available

SECTION 9 NOTES: None

10. STABILITY AND REACTIVITY

STABILITY: Stable.
HAZARDOUS POLYMERIZATION: Will not occur.
CONDITIONS TO AVOID: Will not occur.
INCOMPATIBLE MATERIALS TO AVOID: Do not mix with cleaners, do not freeze, and avoid heat and direct sunlight.

SECTION 10 NOTES: None

11. TOXICOLOGICAL INFORMATION

The following results are for the product:

TOXICITY: Eye Irritation: Minimally irritating to eyes (Rabbit)

SECTION 11 NOTES: None

12. ECOLOGICAL INFORMATION

ECOTOXICOLOGICAL EFFECTS: This pesticide is toxic to fish. Do not apply to water by cleaning of equipment or disposal of pesticide.

SECTION 12 NOTES: None

13. DISPOSAL CONSIDERATIONS

WASTE DISPOSAL METHOD: Waste resulting from the use of this product may be disposed of on site.

SECTION 13 NOTES: None

14. TRANSPORT INFORMATION

U.S. DEPARTMENT OF TRANSPORTATION: Not regulated

SECTION 14 NOTES: None

15. REGULATORY INFORMATION

Not applicable

16. OTHER INFORMATION

PREPARATION INFORMATION: Prepared by IndusCo, Ltd.
DISCLAIMER: This information is offered in good faith as typical values and not as a product specification. No warranty, expressed or implied is hereby made. The recommended industrial hygiene and safe handling procedures are believed to be generally applicable. However, each user should review these recommendations in the specific context of the intended use and determine whether they are appropriate.

Date Issued: 06/24/08
Section 1: PRODUCT & COMPANY IDENTIFICATION

Product Name: D/2 Biological Solution

Manufactured By: D/2 Biological Solution
PO Box 3746
Westport, MA 02790
(917) 693-7441
http://d2bio.com

Emergency Phone: Chem-Tel 24-Hour Emergency Service: (800) 255-3924

Use of Product: D/2 Biological Solution is a biodegradable, easy to use liquid that removes stains from mold, algae, mildew, lichens and air pollutants. It is effective on marble, granite, limestone, brownstone, travertine, masonry, terra cotta, concrete, stucco, wood, and other architectural surfaces including monuments, sculpture and headstones.

Section 2: HAZARDS IDENTIFICATION

D/2 Biological Solution is a colorless liquid with a very faint detergent-like odor.
It is non-flammable, non-combustible, non-explosive, and non-reactive.

<table>
<thead>
<tr>
<th>Hazard Rating (NFPA/HMIS)</th>
<th>Rating Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health = 1*</td>
<td>0 = Minimal</td>
</tr>
<tr>
<td>Reactivity = 0</td>
<td>1 = Slight</td>
</tr>
<tr>
<td>Fire = 0</td>
<td>2 = Moderate</td>
</tr>
<tr>
<td>Special = 0</td>
<td>3 = Serious</td>
</tr>
<tr>
<td>* Mild eye irritant, non-mutagenic and non-carcinogenic</td>
<td>4 = Severe</td>
</tr>
</tbody>
</table>

Eye Contact: Eye Irritant.
Skin Contact: Prolonged skin contact with D/2 Biological Solution may irritate the skin. Repeated daily application to the skin without rinsing, or continuous contact of D/2 Biological Solution on the skin may lead to irritation.
Ingestion: Essentially non-toxic. May cause stomach or intestinal upset if swallowed.
Inhalation: No adverse effects expected under typical use conditions. Adequate ventilation should be present when using D/2 Biological Solution over a prolonged period of time. Open windows or ventilate via fan or other air-moving equipment if necessary. Mucous membranes may become irritated by concentrate mist.
Carcinogens: No ingredients are listed by OSHA, IARC, or NTP as known or suspected carcinogens.
Medical Conditions: No medical conditions are known to be aggravated by exposure to D/2 Biological Solution.

Section 3: COMPOSITION/INFORMATION ON INGREDIENTS

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>CAS Number</th>
<th>OSHA PEL ACGIH TLV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surfactants</td>
<td>Proprietary</td>
<td>None established</td>
</tr>
<tr>
<td>Wetting Agents</td>
<td>Proprietary</td>
<td>None established</td>
</tr>
<tr>
<td>Buffers</td>
<td>Proprietary</td>
<td>None established</td>
</tr>
</tbody>
</table>
Section 4: FIRST AID MEASURES

If in Eyes: Immediately rinse the eye with large quantities of cool water; if present, contact lenses should be removed after 5 minutes of rinsing; continue rinsing 10-15 minutes more. Both upper and lower lids should be lifted to facilitate thorough rinsing.

If on Skin: Minimal effects, if any, from diluted product; rinse skin with water, rinse shoes and launder clothing before reuse. Reversible reddening may occur in some dermal-sensitive users; thoroughly rinse area.

If Inhaled: Use in well-ventilated area, or use adequate protection from inhaling mist during spray applications. Prolonged exposure of workers to concentrate-mist during spray application may cause mild irritation of nasal passages or throat. If this happens, relocate workers to fresh air.

If Ingested: Give several glasses of milk or water to dilute; do not induce vomiting. If stomach upset occurs, consult physician.

Section 5: FIRE FIGHTING MEASURES

Extinguishing Media: Not flammable/non-explosive. No special procedures required.

Special Fire Fighting Procedures: None required.

Section 6: ACCIDENTAL RELEASE MEASURES

Personal Precautions: Avoid contact with eyes. Do not rub eyes with hands during cleanup. No special precautions for dermal contact are needed. Wash hands thoroughly after cleaning up spill or leak.

Procedure to follow in case of spill or leak: Evacuate area. Identify source of leak or spill and contain with sand, earth, or containment bin. Then proceed to clean up spill or leak.

Method for cleaning up: Recover all usable material. Residual may be removed by wipe or wet mope. Rinse area with plenty of water and mop to sanitary sewer.

Section 7: HANDLING AND STORAGE

No special handling is required. Keep in a closed plastic container. Store at ambient temperature. Avoid contact with eyes. Wash hands thoroughly after handling. This product is non-hazardous for storage and transport according to the U.S. Department of Transportation Regulations.

This material does not meet the definition of a hazardous material according to 49 CFR, ICAO, IMDG and the UN Orange Book.

Section 8: EXPOSURE CONTROLS/PERSONAL PROTECTION

Precautionary measures: No special requirements under normal use conditions.

Exposure Limits: The D/2 Biological Solution formulation presents no health hazards to the user, other than mild eye irritation.

Eye protection: Caution, including reasonable eye protection, should always be used to avoid eye contact where splashing may occur, such as during spray applications.

Respiratory Protection: No special precautions required.

Ventilation: No special ventilation is required during normal use.

Skin protection: No special precautions required; rinse completely from skin after contact.
Section 8: EXPOSURE CONTROLS/PERSONAL PROTECTION (cont’d)

General hygiene conditions: There are no known hazards associated with this material when used as recommended. The following general hygiene considerations are recognized as common good industrial hygiene practices:

- Avoid breathing vapor or mist.
- Avoid contact with eyes.
- Wash thoroughly after handling and before eating, drinking, or smoking.

Section 9: PHYSICAL AND CHEMICAL PROPERTIES

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance</td>
<td>Clear Liquid</td>
</tr>
<tr>
<td>Odor</td>
<td>Very faint detergent-like odor</td>
</tr>
<tr>
<td>pH</td>
<td>9.5</td>
</tr>
<tr>
<td>Evaporation Rate</td>
<td>0.4 (butyl acetate = 1)</td>
</tr>
<tr>
<td>Water Solubility</td>
<td>100%</td>
</tr>
<tr>
<td>Freezing Point</td>
<td>-9 °C (16 °F)</td>
</tr>
<tr>
<td>Boiling Point</td>
<td>98 °C (209 °F)</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>1.011</td>
</tr>
<tr>
<td>Vapor Pressure</td>
<td>20.7 mm Hg</td>
</tr>
<tr>
<td>Vapor Density</td>
<td>1.3 (air = 1)</td>
</tr>
</tbody>
</table>

Section 10: STABILITY AND REACTIVITY

Stability: Stable.
Materials to Avoid: Contains ammoniated compounds – do not mix with bleach, tub & tile cleaner, mold/mildew removers, or chlorinated compounds.

Hazardous Decomposition Products: None expected

Section 11: TOXICOLOGICAL INFORMATION

Toxicity Data: Available from relevant laboratory testing of ingredients or similar mixtures.
Acute Toxicity:
- Oral LD50: >2.0 g/kg body weight
- Dermal LD50: Not estimated
Eye Irritation: With or without rinsing with water, the irritation scores in rabbits at 24 hours did not exceed 17 (mild irritant) on a scale of 110 (extremely irritating); all scores were normal at seven days.
Dermal Irritation: In a standard test on rabbits, mild irritation was found at 72 hours; well-defined reddening was observed at 7 and 14 days after exposure.
Dermal Sensitization: No allergic reactions occurred in guinea pigs treated with D/2 Biological Solution.
Carcinogenicity: D/2 Biological Solution contains no carcinogenic compounds as defined by the National Toxicology Program (NTP), the international Agency for Research on Carcinogens (IARC), or the Occupational Health and Safety Administration (OSHA).

Section 12: ECOLOGICAL INFORMATION

Biodegradability: All components are inherently biodegradable.
Ecotoxicity: Not Tested.

Section 13: DISPOSAL CONSIDERATIONS

Unused Product: Dilute with water 1:10 (1 part D/2 to 10 parts water) and dispose by sanitary sewer.
Used Product: Used product may be hazardous depending on the cleaning application and resulting contaminants.
Empty Containers: Triple-rinse with water and offer for recycling if available. Otherwise, dispose as non-hazardous waste.

Dispose of used or unused product, and empty containers in accordance with the local, State, Provincial, and Federal regulations for your location. Never dispose of used degreasing rinsates into lakes, streams, and open bodies of water or storm drains.
Section 14: TRANSPORT INFORMATION

This product is non-hazardous for storage and transport according to the U.S. Department of Transportation Regulations. D/2 Biological Solution requires no special labeling or placarding to meet U.S. Department of Transportation requirements.

IATA Proper Shipping Name: Detergent solution
Hazard Class: Nonhazardous
UN Number: Not Required

Section 15: REGULATORY INFORMATION

Reportable components: None. The U.S. Environmental Protection Agency (EPA) has determined that propylene glycol ethers are not included within the listed category "glycol ethers" under either EPCRA §313 Toxic Release Inventory or Clean Air Act §112 Hazardous Air Pollutants (both lists include only ethylene glycol ethers). Nor are propylene glycol ethers included in the various EPA Resource Conservation and Recovery Act, and Clean Water Act lists, nor the California Proposition 65 lists.

All components are listed on: EINECS and TSCA Inventory
No components listed under: Clean Air Act Section 112

RCRA Status: Not a hazardous waste. CERCLA Status: No components listed
TSCA TRI Reporting: Not required / Not listed CA PROP. 65 Status: No components listed

Section 16: OTHER INFORMATION

Technical information contact:
D/2 Biological Solution
PO Box 3746
Westport, MA 02790
(917) 693-7441
http://d2bio.com

DISCLAIMER: All information appearing herein is based upon data obtained by the manufacturer and recognized technical sources. Judgments as to the suitability of information herein for purchaser’s purposes are necessarily purchaser’s responsibility. Therefore, although reasonable care has been taken in the preparation of this information, D/2 Biological Solutions, Inc. or its distributors extends no warranties, makes no representations and assumes no responsibility as to the suitability of such information for application to purchaser’s intended purposes or for consequences of its use.
Sure-Klean® Limestone & Masonry Afterwash, a mild organic acid cleaning compound, neutralizes and brightens surfaces that have been pre-washed with Sure-Klean® 766 Limestone & Masonry Prewash. When used properly, this two-part cleaning system removes heavy carbon, dirt and other atmospheric stains from porous limestone, concrete and most other porous masonry surfaces. 766 Limestone & Masonry Prewash and Limestone & Masonry Afterwash will not damage most masonry surfaces.

As part of the Enviro-Klean® ReKlaim system, Limestone & Masonry Afterwash helps remove combinations of atmospheric and biological staining that blacken limestone, marble, concrete and other masonry surfaces in humid environments.

Limestone & Masonry Afterwash also provides effective surface neutralization on masonry cleaned with Sure-Klean® Heavy Duty Paint Stripper.

**Advantages**
- Does not contain hydrochloric (muriatic) or hydrofluoric acid.
- Concentrated for economy.
- Easy to apply with brush, roller or low-pressure spray.

**Limitations**
- On severely stained brick, terra cotta, sandstone or granite, improved cleaning results may be achieved with an alternative Sure-Klean® afterwash product. Following use of Sure-Klean® 766 Limestone & Masonry Prewash, test Sure-Klean® Light Duty Restoration Cleaner, Restoration Cleaner or Heavy Duty Restoration Cleaner to determine the most effective cleaning system.

**Specifications**
For all PROSOCO product specifications visit www.prosoco.com.
Limestone & Masonry Afterwash

PREPARATION
Protect people, vehicles, property, plants and all non-masonry surfaces from product, splash, rinse, residue, wind drift and fumes. Divert and/or protect pedestrian and auto traffic.

Surface and Air Temperatures
Temperatures below 50°F (10°C) reduce cleaning effectiveness. Do not apply below 40°F (4°C). If freezing conditions exist prior to application, let masonry thaw.

Equipment
Apply with a soft-fibered, masonry wash brush or low-pressure spray equipment. Do not apply with pressure above 50 psi. This drives the cleaner into the surface, making complete rinse difficult. Stains may result. Fit equipment with acid-resistant hoses and gaskets.

Rinse with enough water and pressure to flush spent cleaner and dissolved soiling from the masonry surface and surface pores without damage. Inadequate rinsing leaves residues which may stain the cleaned surface.

Masonry-washing equipment generating 400–1000 psi with a water flow-rate of 6–8 gallons per minute is the best water/pressure combination for rinsing porous masonry. Use a 15–45 degree fan spray tip. Heated water (150–180°F; 65–82°C) may improve cleaning efficiency. Use adjustable equipment for reducing water flow-rates and rinsing pressure as needed for sensitive surfaces.

Rinsing pressures greater than 1000 psi and fan spray tips smaller than 15 degrees may permanently damage sensitive masonry. Water flow-rates less than 6 gallons per minute may reduce cleaning productivity and contribute to uneven clearing results.

Storage and Handling
Store in a cool, dry place with adequate ventilation. Always seal container after dispensing. Do not alter or mix with other chemicals. Published shelf life assumes upright storage of factory-sealed containers in a dry place.

ALWAYS TEST
ALWAYS TEST a small area of each surface to confirm suitability and desired results before starting overall application. Test with the same equipment, recommended surface preparation and application procedures planned for general application.

Maintain temperature of 45–100°F (7–38°C). Do not double stack pallets. Dispose of unused product and container in accordance with local, state and federal regulations.

APPLICATION
Before use, read "Preparation" and "Safety Information."

ALWAYS TEST each type of surface and each type of stain for suitability, dilution and desired results before overall application. Test using the following application instructions. Let the surface dry thoroughly before inspection.

Dilution
Dilute one part fresh water to one part concentrated cleaner before application. Always pour cold water into empty polyethylene or polypropylene bucket, then carefully add concentrate. Never pour water into cleaner.

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Type</th>
<th>Use?</th>
<th>Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architectural Concrete Block</td>
<td>Burnished Smooth Split-faced Ribbed</td>
<td>yes</td>
<td>75–150 sq.ft. 7–14 sq.m.</td>
</tr>
<tr>
<td>Concrete</td>
<td>Brick</td>
<td>yes</td>
<td>100–200 sq.ft. 9–19 sq.m.</td>
</tr>
<tr>
<td></td>
<td>Tile</td>
<td>yes</td>
<td>100–200 sq.ft. 9–19 sq.m.</td>
</tr>
<tr>
<td></td>
<td>Precast Panels Pavers Cast-in-place</td>
<td>yes</td>
<td>100–200 sq.ft. 9–19 sq.m.</td>
</tr>
<tr>
<td>Fired Clay</td>
<td>Brick</td>
<td>yes</td>
<td>100–200 sq.ft. 9–19 sq.m.</td>
</tr>
<tr>
<td></td>
<td>Tile</td>
<td>yes</td>
<td>100–200 sq.ft. 9–19 sq.m.</td>
</tr>
<tr>
<td></td>
<td>Terra Cotta</td>
<td>yes</td>
<td>100–200 sq.ft. 9–19 sq.m.</td>
</tr>
<tr>
<td>Marble, Travertine, Limestone Polished</td>
<td>Unpolished</td>
<td>yes</td>
<td>150–200 sq.ft. 14–19 sq.m.</td>
</tr>
<tr>
<td>Granite</td>
<td>Polished</td>
<td>yes</td>
<td>250–400 sq.ft. 23–37 sq.m.</td>
</tr>
<tr>
<td></td>
<td>Unpolished</td>
<td>yes</td>
<td>200–300 sq.ft. 19–28 sq.m.</td>
</tr>
<tr>
<td>Sandstone</td>
<td>Unpolished</td>
<td>yes</td>
<td>100–200 sq.ft. 9–19 sq.m.</td>
</tr>
<tr>
<td>Slate</td>
<td>Unpolished</td>
<td>yes</td>
<td>200–300 sq.ft. 19–28 sq.m.</td>
</tr>
</tbody>
</table>

Recommended for these substrates. Always test.
Coverage is in sq.ft./m. per gallon of concentrate.

Always test to ensure desired results.
Coverage estimates depend on surface texture and porosity.
Application Instructions
Use Limestone & Masonry Afterwash as a follow-up treatment to Sure Klean® 766 Limestone & Masonry Prewash, Enviro Klean® ReKlain and Sure Klean® Heavy Duty Paint Stripper. Limestone & Masonry Afterwash works as part of these two-part cleaning systems to completely restore and neutralize masonry surfaces.

1. Immediately after rinsing the primary cleaner from masonry surface, apply the prepared Afterwash to the wet surface working from the bottom of the work area to the top.
2. Let the Afterwash dwell for three to five minutes.
3. Pressure rinse from the bottom of the treated area to the top. Make sure to cover each portion of the masonry surface with a concentrated stream of water. To avoid streaking, keep wall surfaces immediately below area being cleaned running wet and free of cleaner rundown and residues.
4. Using pH papers, pH pen or pH indicator solutions, check treated surfaces to ensure neutralization has been achieved. Repeat steps 1–3 above if needed until surface pH is 5.0 to 9.0.
5. Let neutralized surface dry thoroughly. Before applying new surface coatings, check the cleaned surface again using pH papers, pH pen or pH indicator solutions. Check that surface pH is neutral. Inadequate neutralization may cause surface discoloration or failure of new surface coatings.

Cleanup
Clean tools and equipment using fresh water.

SAFETY INFORMATION
Sure Klean® Limestone & Masonry Afterwash is an acidic cleaning product with safety issues common to corrosive materials. Use appropriate safety equipment and job site controls during application and handling. Read the full label and MSDS for precautionary instructions before use.

First Aid
Ingestion: If conscious, give large amounts of milk or water and call a physician, emergency room or poison control center immediately. Do not induce vomiting.

Eye Contact: Rinse eyes thoroughly for 15 minutes. Get immediate medical assistance.

Skin Contact: Remove contaminated clothing and rinse thoroughly for 15 minutes. Get medical attention. Discard contaminated clothing and shoes that can’t be adequately laundered.

Inhalation: Remove to fresh air. Give artificial respiration if not breathing. Get immediate medical attention.

24 Hour Emergency Information:
INFOTRAC at 800-535-5053

BEST PRACTICES
Use Limestone & Masonry Afterwash as a follow-up treatment to Sure Klean® 766 Limestone & Masonry Prewash, Enviro Klean® ReKlain and Sure Klean® Heavy Duty Paint Stripper. Limestone & Masonry Afterwash works as part of these two-part cleaning systems to completely restore and neutralize masonry surfaces.

Do not apply with pressure above 50 psi. This drives the cleaner into the surface, making complete rinse difficult. Stains may result.

Rinse with enough water and pressure to flush spent cleaner and dissolved soiling from the masonry surface and surface pores without damage. Inadequate rinsing leaves residues which may stain the cleaned surface.

Never go it alone. For problems or questions, contact your local PROSOCO distributor or field representative. Or call PROSOCO technical Customer Care toll-free at 800-255-4255.
**WARRANTY**

The information and recommendations made are based on our own research and the research of others, and are believed to be accurate. However, no guarantee of their accuracy is made because we cannot cover every possible application of our products, nor anticipate every variation encountered in masonry surfaces, job conditions and methods used. The purchasers shall make their own tests to determine the suitability of such products for a particular purpose.

PROSOCO, Inc. warrants this product to be free from defects. Where permitted by law, PROSOCO makes no other warranties with respect to this product, express or implied, including without limitation the implied warranties of merchantability or fitness for particular purpose. The purchaser shall be responsible to make his own tests to determine the suitability of this product for his particular purpose. PROSOCO’s liability shall be limited in all events to supplying sufficient product to re-treat the specific areas to which defective product has been applied. Acceptance and use of this product absolves PROSOCO from any other liability, from whatever source, including liability for incidental, consequential or resultant damages whether due to breach of warranty, negligence or strict liability. This warranty may not be modified or extended by representatives of PROSOCO, its distributors or dealers.

**CUSTOMER CARE**

Factory personnel are available for product, environment and job-safety assistance with no obligation. Call 800-255-4255 and ask for Customer Care - technical support.

Factory-trained representatives are established in principal cities throughout the continental United States. Call Customer Care at 800-255-4255, or visit our web site at www.prosoco.com, for the name of the Sure Klean® representative in your area.
### I PRODUCT IDENTIFICATION

**MANUFACTURER’S NAME**: PROSOCO, Inc.  
**AND ADDRESS**: 3741 Greenway Circle, Lawrence, KS 66046  
**EMERGENCY TELEPHONE NUMBERS**:  
- 8:00 AM – 5:00 PM CST Monday-Friday: 785/865-4200  
- NON-BUSINESS HOURS (INFOTRAC): 800/535-5053  
**PRODUCT TRADE NAME**: Sure Klean® Limestone & Masonry Afterwash

### II HAZARDOUS INGREDIENTS

<table>
<thead>
<tr>
<th>CHEMICAL NAME</th>
<th>(COMMON NAME)</th>
<th>CAS NO.</th>
<th>NFPA CODE</th>
<th>ACGIH TLV/TWA</th>
<th>OSHA PEL/TWA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethanoic Acid</td>
<td>(Acetic Acid, Glacial)</td>
<td>64-19-7</td>
<td>3,2,0,-</td>
<td>10 ppm</td>
<td>10 ppm</td>
</tr>
<tr>
<td>Organic Acid*</td>
<td></td>
<td></td>
<td>1,0,0,-</td>
<td>Not Listed</td>
<td>Not Listed</td>
</tr>
</tbody>
</table>

* Specific chemical identity and percentage content of hazardous ingredients withheld as trade secret pursuant to OSHA regulations.

### III PHYSICAL DATA

<table>
<thead>
<tr>
<th></th>
<th>BOILING POINT (°F)</th>
<th>VAPOR PRESSURE (mm Hg)</th>
<th>VAPOR DENSITY (Air = 1)</th>
<th>EVAPORATION RATE (Butyl Acetate = 1)</th>
<th>SPECIFIC GRAVITY</th>
<th>pH</th>
<th>SOLUBILITY IN WATER</th>
<th>APPEARANCE AND ODOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethanoic Acid</td>
<td>245°F</td>
<td>15.70 (68°F)</td>
<td>2.07</td>
<td>.97</td>
<td>1.02</td>
<td>1.10 (concentrate)</td>
<td>Complete</td>
<td>Clear liquid, pungent, vinegar-like odor</td>
</tr>
<tr>
<td>Organic Acid</td>
<td>&gt;212°F</td>
<td>Not Available</td>
<td>Not Available</td>
<td>&lt;1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limestone &amp; Masonry Afterwash</td>
<td>1.02</td>
<td>1.10 (concentrate)</td>
<td>Complete</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### IV FIRE AND EXPLOSION HAZARD DATA

**EMERGENCY OVERVIEW**

Sure Klean® Limestone & Masonry Afterwash is a clear liquid with a strong, pungent, vinegar-like odor. Vapors may cause severe respiratory tract irritation, and contact with skin or eyes may result in burns or severe irritation. Always wear appropriate personal protection equipment when handling this product.

**FLASH POINT (METHOD)**: >200°F (ASTM D 93)

**FLAMMABLE LIMITS**: Not determined.

**EXTINGUISHING MEDIA**: Use dry chemical, alcohol foam, all purpose AFFF or carbon dioxide to extinguish fire. Water may be ineffective but should be used to cool fire-exposed containers, structures, and to protect personnel.

**SPECIAL FIRE FIGHTING PROCEDURES**: Wear NIOSH/MSHA approved positive pressure self-contained breathing apparatus with full face mask and full protective clothing when fighting fires. Use water spray to cool fire-exposed structures and storage tanks and to disperse vapor cloud if fire is not present.

**UNUSUAL FIRE AND EXPLOSION HAZARDS**: Vapors can form flammable or explosive mixtures with air. Do not cut, drill, or weld on or near full or empty containers because the product or residue from the product could ignite explosively in the container.

### V HEALTH HAZARD DATA
PRIMARY ROUTES OF EXPOSURE: Skin, eyes, inhalation, ingestion.

CARCINOGEN INFORMATION: Not listed (OSHA, IARC, NTP).

MEDICAL CONDITIONS AGGRAVATED BY OVEREXPOSURE: No applicable information found.

EFFECTS OF OVER EXPOSURE: Causes severe damage to eyes and even blindness very rapidly. Causes burns, possible deep ulceration to skin. Breathing of mist or dust can cause damage to nasal and respiratory passages. Swallowing results in severe damage to mucous membranes and deep tissue.

EYE CONTACT: Liquid or concentrated vapors can cause eye irritation, severe burns and permanent damage, including blindness, even after a short exposure to small amounts. Direct contact may cause conjunctivitis, redness, pain, blurred vision, conjunctival and corneal destruction and permanent injury.

SKIN CONTACT: Liquid or concentrated vapors can rapidly cause burning of skin, as well as reddening, itching, inflammation, blistering, and tissue damage. Repeated or prolonged contact with dilute solutions and concentrated vapors can cause irritation and dermatitis.

INHALATION: May cause irritation, coughing, chest pain, difficulty in breathing. Prolonged exposure to high vapor concentrations may result in the inhalation of harmful amounts of material. Repeated exposure to high vapor concentrations may produce respiratory tract irritation with pharyngeal edema, chronic bronchitis, discoloration of teeth and thickening of the skin.

INGESTION: Causes burning abdominal pain, nausea, vomiting, shock state, collapse. Causes severe irritation or chemical burns of mouth, throat, esophagus, and stomach, followed by nausea, abdominal spasms, vomiting, hematemesis and diarrhea.

EMERGENCY AND FIRST AID PROCEDURES:

EYE CONTACT: Rinse eyes with large quantities of water for at least 15 minutes, holding eyelids apart to ensure flushing of the entire eye surface. Get medical attention immediately. If physician is not immediately available, continue flushing with water. Do not use a chemical antidote.

SKIN CONTACT: Remove contaminated clothing and flush exposed area with large quantities of water for at least 15 minutes. Discard contaminated clothing and leather goods that cannot be adequately laundered to remove all traces of material. Get immediate medical attention.

INHALATION: Remove person to fresh air. If breathing stops, administer artificial respiration, preferably mouth-to-mouth. If breathing is difficult, give oxygen. Keep affected person warm and at rest. Get medical attention immediately.

INGESTION: If conscious, give large quantities of water or milk. Do not induce vomiting. Get medical attention immediately. If large volumes are swallowed, acidosis may occur and require appropriate acid-base management.

VI REACTIVITY DATA

STABILITY: Stable.

CONDITIONS TO AVOID: Contact with strong bases (alkali), chromic acid, nitric acid, amines, and oxidizing materials can cause violent reaction generating large amounts of heat.

INCOMPATIBILITY (MATERIALS TO AVOID): Metals, oxidizing agents, nitric acid, hydrofluoric acid, chromic acid, alkalies, amines, and strong mineral acids.

HAZARDOUS COMBUSTION OR DECOMPOSITION PRODUCTS: Irritating and toxic fumes may be emitted upon decomposition. Combustion may produce CO and CO₂. Reactions with metals may produce hydrogen gas. Can be dangerously reactive with strong acids or oxidizing agents.

VII SPILL OR LEAK PROCEDURES

SPILL, LEAK, WASTE DISPOSAL PROCEDURES: Evacuate immediate area where concentrated fumes are present. Cleanup personnel must wear proper protective equipment. Completely contain spilled material with dikes, etc., and prevent runoff into ground and surface waters or into sewers. Dilute with water. Spills and leaks should be neutralized by pouring dry soda ash or lime over the affected area to adjust pH to neutral. Allow powdered material to remain on spill for five to ten minutes and flush thoroughly with water. Neutralized material, both liquid and solid, must be recovered for proper disposal.

WASTE DISPOSAL METHODS: Neutralized materials may be discharged to a sanitary sewer with approval of local sewerage authorities. Product as supplied is classified as a hazardous waste under USEPA regulations for the characteristic of corrosivity. Recovered solids or liquids may be sent to a licensed reclaimer or disposed of in a permitted waste management facility. Consult federal, state, and/or local authorities for approved procedure.
VIII SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION: For vapor or mist concentrations which exceed or are likely to exceed 10 ppm Threshold Limit Value (TLV), wear a NIOSH/MSHA approved full-face respirator with organic vapor cartridges. NIOSH/MSHA approved self-contained or air supplied breathing apparatus with full-face piece should be worn when in high concentrations. Follow all applicable respirator use, standards or regulations.

VENTILATION: Provide sufficient general and/or local exhaust ventilation to maintain exposure below the TLV.

PROTECTIVE CLOTHING: Wear neoprene or polyethylene rain suit.

PROTECTIVE GLOVES: Butyl rubber, neoprene or polyethylene with acceptable acid resistance.

EYE PROTECTION: Chemical splash goggles and/or full face shield (8 inch minimum) in compliance with OSHA regulations. Do not wear contact lenses because they may contribute to the severity of an eye injury.

OTHER PROTECTIVE EQUIPMENT: Acid-resistant rubber boots, headgear. Eyewash and safety shower should be easily accessible.

IX SPECIAL PRECAUTIONS

WORK PRACTICES: Proper work practices and planning should be utilized to avoid contact with workers, passersby, and non-masonry surfaces. Do not atomize during application. Beware of wind drift. Pre-rinsing with low-pressure water prior to pressure washing will minimize wind-drift concerns. Protect building occupants during application. See the Product Data sheet and label for specific precautions to be taken during use. Smoking, eating and drinking should be prohibited during the use of this product. Wash hands before breaks and at the end of a shift. Do not alter this product or use for purposes other than specified.

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: Use proper safety equipment (see section VIII) when handling. Store in a cool, well-ventilated area. Separate from oxidizing agents, nitric acid, alkalis, chlorates, sulfides, etc. (see section VI). Dilution and application equipment should be of HDPE or polypropylene construction. Keep product container and dilution vessels closed when not dispensing.

Addition of acidic cleaner to water releases heat, which can result in violent boiling and spattering. Always add cleaner to water slowly and in small amounts. Never use hot water. Never add water to acidic cleaners.

Containers of this material may be hazardous when emptied, since emptied containers retain product residues (vapor, liquid, and/or solid). All hazard precautions given in this data sheet must be observed.

OTHER PRECAUTIONS: Do not get in eyes, on skin or on clothing. Can cause severe injury or blindness. Avoid breathing mist or vapor. Provide ventilation sufficient to limit employee exposure below OSHA permissible limit. Do not take internally. Wash thoroughly after handling.

X REGULATORY INFORMATION

SHIPPING: This product carries the proper shipping description UN2790, Acetic Acid Solution, 8, II in domestic or international shipments. Some container sizes are restricted in air transport. Consult with PROSOCO’s Regulatory Department for assistance.

NATIONAL MOTOR FREIGHT CLASSIFICATION: NMFC #: 44157 Sub 3 Class Rate: 85

SARA 313 REPORTABLE:

<table>
<thead>
<tr>
<th>CHEMICAL NAME</th>
<th>CAS</th>
<th>UPPERBOUND CONCENTRATION % BY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>NA</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CALIFORNIA PROPOSITION 65: Contains no chemicals listed under California’s Proposition 65.
DISCLAIMER:

The information contained on the Material Safety Data Sheet has been compiled from data considered accurate. This data is believed to be reliable, but it must be pointed out that values for certain properties are known to vary from source to source. PROSOCO, Inc. expressly disclaims any warranty express or implied as well as any liability for any injury or loss arising from the use of this information or the materials described. This data is not to be construed as absolutely complete since additional data may be desirable when particular conditions or circumstances exist. It is the responsibility of the user to determine the best precautions necessary for the safe handling and use of this product for his unique application. This data relates only to the specific material designated and is not to be used in combination with any other material. Many federal and state regulations pertain directly or indirectly to the product’s end use and disposal of containers and unused material. It is the purchaser’s responsibility to familiarize himself with all applicable regulations.

DATE OF PREPARATION: September 9, 2010
SURE-KLEAN®

Limestone Restorer
unpolished limestone & cast stone cleaner

OVERVIEW
Sure Klean® Limestone Restorer is a concentrated acidic cleaner for unpolished limestone, concrete and cast stone surfaces. Safely removes atmospheric dirt, mildew and many other surface stains without risk of bleaching or discoloration.

Ideal for lightly to moderately soiled surfaces. Limestone Restorer is safer and easier to use than conventional acid or abrasive cleaning systems. Contains no hydrofluoric acid. Use in combination with pressure water rinsing.

SPECIFICATIONS
For all PROSOCO product specifications visit www.prosoco.com.

ADVANTAGES
• Easy-to-use, one step cleaner.
• Water rinsable — No substrate neutralization required.
• When properly used, safer for surfaces than conventional cleaning systems.
• Will not damage window glass.

Limitations
• Not for use on polished granite, limestone, marble or travertine.
• May etch smooth, acid-sensitive surfaces.
• On fired clay brick and pavers that are prone to metallic staining, Sure Klean® Restoration Cleaner or Light Duty Restoration Cleaner may be more suitable.
• Not for removal of heavy carbon staining. Use Sure Klean® 766 Limestone & Masonry Prewash.

REGULATORY COMPLIANCE
VOC Compliance
Sure Klean® Limestone Restorer is compliant with all national, state and district regulations.

TYPICAL TECHNICAL DATA

| FORM | Clear liquid, light amber color |
| SPECIFIC GRAVITY | 1.14 |
| pH | 0.18 @ 1.6 dilution |
| WT/GAL | 9.47 lbs |
| ACTIVE CONTENT | Not applicable |
| TOTAL SOLIDS | Not applicable |
| VOC CONTENT | Not applicable |
| FLASH POINT | Not applicable |
| FREEZE POINT | < -22°F (< -30°C) |
| SHELF LIFE | 3 years in tightly sealed, unopened container |
SURE-KLEAN

Limestone Restorer

PREPARATION

Protect people, vehicles, property, plants, and all non masonry and acid-sensitive surfaces from cleaner, rinse, residue, fumes and wind drift.

Protect and/or divert auto and pedestrian traffic.

Finish cleaning before installing windows, doors, hardware, light fixtures, roofing materials and other non masonry items. If already installed, protect before cleaning. Caulking and sealant materials should be in place and thoroughly cured before cleaning begins.

Surface and Air Temperatures

Cleaning when temperatures are below freezing or will be overnight may harm masonry. If freezing conditions have existed, let masonry thaw before cleaning.

Equipment

Apply using a densely-filled masonry washing (tampico) brush, roller or low pressure (50 psi maximum) spray. Do not apply with high pressure spray equipment. This drives the cleaner deep into the surface, making complete rinse difficult. Discoloration may result.

Rinse with enough water and pressure to flush spent cleaner and dissolved soiling from the masonry surface and surface pores without damage. Inadequate rinsing leaves residues which may stain the cleaned surface.

Masonry-washing equipment generating 400—1000 psi with a water flow rate of 6—8 gallons per minute is the best water/pressure combination for rinsing porous masonry. Use a 15—45° fan spray tip. Heated water (150—180°F; 65—82°C) may improve cleaning efficiency. Use adjustable equipment for reducing water flow-rates and rinsing pressure as needed for sensitive surfaces.

Rinsing pressures greater than 1000 psi and fan spray tips smaller than 15° may permanently damage sensitive masonry. Water flow-rates less than 6 gallons per minute may reduce cleaning productivity and contribute to uneven cleaning results.

ALWAYS TEST a small area of each surface to confirm suitability and desired results before starting overall application. Test with the same equipment, recommended surface preparation and application procedures planned for general application.

Storage and Handling

Store in a cool, dry place with adequate ventilation. Always seal container after dispensing. Do not alter or mix with other chemicals. Published shelf life assumes upright storage of factory-sealed containers in a dry place. Maintain temperature of 45—100°F (7—38°C). Do not double stack pallets. Dispose of unused product and container in accordance with local, state and federal regulations.

APPLICATION

Before use, read "Preparation" and "Safety Information."

ALWAYS TEST each type of surface and each type of stain for suitability, dilution and desired results before overall application. Test using the following application instructions. Let the surface dry thoroughly before inspection.

Dilution

Dilute with a minimum two parts and up to six parts water to one part concentrate. Test panels should determine effectiveness of the cleaning solution and proper dilution ratio.

When diluting, pour cold water into empty polypropylene or polyethylene bucket, then carefully add cleaner. Acidic liquids and fumes attack metal.

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Type</th>
<th>Use?</th>
<th>Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architectural Concrete</td>
<td>Burnished</td>
<td>yes</td>
<td>100—300 sq.ft.</td>
</tr>
<tr>
<td>Block*</td>
<td>Smooth</td>
<td>yes</td>
<td>9—28 sq.m.</td>
</tr>
<tr>
<td></td>
<td>Split-faced</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ribbed</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Concrete*</td>
<td>Brick</td>
<td>yes</td>
<td>100—300 sq.ft.</td>
</tr>
<tr>
<td></td>
<td>Tile</td>
<td>yes</td>
<td>9—28 sq.m.</td>
</tr>
<tr>
<td></td>
<td>Precast Panels</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pavers</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cast-in-place</td>
<td>yes</td>
<td></td>
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<tr>
<td>Fired Clay</td>
<td>Brick*</td>
<td>yes</td>
<td>300—700 sq.ft.</td>
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<td></td>
<td>Tile</td>
<td>no</td>
<td>28—65 sq.m.</td>
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<tr>
<td></td>
<td>Terra Cotta</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Pavers*</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Marble, Travertine,</td>
<td>Polished</td>
<td>no</td>
<td>N/A</td>
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<tr>
<td>Limestone*</td>
<td>Unpolished</td>
<td>yes</td>
<td>100—250 sq.ft.</td>
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<td></td>
<td></td>
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<td>9—28 sq.m.</td>
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<tr>
<td>Granite*</td>
<td>Polished</td>
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<td>N/A</td>
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<td></td>
<td>Unpolished</td>
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<td>N/A</td>
</tr>
<tr>
<td>Sandstone*</td>
<td>Unpolished</td>
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<td>Smooth</td>
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<td>N/A</td>
</tr>
<tr>
<td>Slate*</td>
<td>Unpolished</td>
<td>no</td>
<td>N/A</td>
</tr>
</tbody>
</table>

*Repeats applications may result in surface etching.

**Sure-Klean** Restoration Cleaner or Light Duty Restoration Cleaner may be more suitable. Always test to ensure desired results.

Coverage estimates depend on surface texture and porosity.

Product Data Sheet • Page 2 of 4 • Item #20034 • SKLR - 032013 • ©2013 PROSOCO • www.prosoco.com
Limestone Restorer

Application Instructions
1. Working from bottom to the top, pre-wet the surface with clean water.
2. Apply the diluted cleaner liberally to the masonry surface using low pressure spray (50 psi max), roller or brush.
3. Let the cleaning solution dwell 3-5 minutes. Reapply. Light agitation improves cleaning results.
4. Working from bottom to the top, rinse the treated area thoroughly. If pressure water equipment is not available, use a garden hose with nozzle adjusted to a tight stream.

Cleanup
Clean tools and equipment using fresh water.

SAFETY INFORMATION
Sure Kleen® Limestone Restorer is a concentrated acidic cleaner. This product may damage a variety of common construction materials and has safety issues common to corrosive materials. Use appropriate safety equipment and job site controls during application and handling. Read the full label and MSDS for precautionary instructions before use.

First Aid
Ingestion: If conscious, give large amounts of milk or water and call a physician, emergency room or poison control center immediately. Do not induce vomiting.

Eye Contact: Rinse eyes thoroughly for 15 minutes. Get immediate medical assistance.

Skin Contact: Remove contaminated clothing and rinse thoroughly for 15 minutes. Get medical attention. Launder contaminated clothing before reuse.

Inhalation: Remove to fresh air. Give artificial respiration if not breathing. Get immediate medical attention.

24-Hour Emergency Information:
INFOTRAC at 800-535-5053

WARRANTY
The information and recommendations made are based on our own research and the research of others, and are believed to be accurate. However, no guarantee of their accuracy is made because we cannot cover every possible application of our products, nor anticipate every variation encountered in masonry surfaces, job conditions and methods used. The purchasers shall make their own tests to determine the suitability of such products for a particular purpose.

PROSOCO, Inc. warrants this product to be free from defects. Where permitted by law, PROSOCO makes no other warranties with respect to this product, express or implied, including without limitation the implied warranties of merchantability or fitness for particular purpose. The purchaser shall be responsible to make his own tests to determine the suitability of this product for his particular purpose. PROSOCO’s liability shall be limited in all events to supplying sufficient product to re-treat the specific areas to which defective product has been applied. Acceptance and use of this product absolves PROSOCO from any other liability, from whatever source, including liability for incidental, consequential or resultant damages whether due to breach of warranty, negligence or strict liability. This warranty may not be modified or extended by representatives of PROSOCO, its distributors or dealers.

CUSTOMER CARE
Factory personnel are available for product, environment and job-safety assistance with no obligation. Call 800-255-4255 and ask for Customer Care - technical support.

Factory-trained representatives are established in principal cities throughout the continental United States. Call Customer Care at 800-255-4255, or visit our website at www.prosoco.com, for the name of the Sure Kleen® representative in your area.
MATERIAL SAFETY DATA SHEET
PROSOCO, Inc.

I PRODUCT IDENTIFICATION

MANUFACTURER'S NAME AND ADDRESS: PROSOCO, Inc.
3741 Greenway Circle
Lawrence, KS 66046

EMERGENCY TELEPHONE NUMBERS:
8:00 AM – 5:00 PM CST Monday-Friday: 785-865-4200
NON-BUSINESS HOURS (INFOTRAC): 800/535-5053

PRODUCT TRADE NAME: Sure Klean\textsuperscript{\textregistered} Limestone Restorer

II HAZARDOUS INGREDIENTS

<table>
<thead>
<tr>
<th>CHEMICAL NAME</th>
<th>(COMMON NAME)</th>
<th>CAS NO.</th>
<th>NFPA CODE</th>
<th>ACGIH TLV/TWA</th>
<th>OHSA PEL/TWA</th>
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</thead>
<tbody>
<tr>
<td>Glycolic Acid</td>
<td>(Hydroxyacetic Acid)</td>
<td>79-14-1</td>
<td>3,0,0,-</td>
<td>10 mg/m\textsuperscript{3} (manufacturer AEL)</td>
<td>10 mg/m\textsuperscript{3} (manufacturer AEL)</td>
</tr>
<tr>
<td>Hydrogen Chloride Solution</td>
<td>(Hydrochloric Acid)</td>
<td>7647-01-0</td>
<td>3,0,0,-</td>
<td>5 ppm (Ceiling)</td>
<td>5 ppm (Ceiling)</td>
</tr>
</tbody>
</table>

Percent content of hazardous ingredients withheld as trade secret pursuant to Massachusetts regulations.

III PHYSICAL DATA

<table>
<thead>
<tr>
<th></th>
<th>BOILING POINT (°F)</th>
<th>VAPOR PRESSURE (mm Hg)</th>
<th>VAPOR DENSITY</th>
<th>EVAPORATION RATE (1=Butyl Acetate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glycolic Acid</td>
<td>234°F</td>
<td>17.5 (68°F)</td>
<td>Vapor is water</td>
<td>NE</td>
</tr>
<tr>
<td>Hydrogen Chloride Solution</td>
<td>150°F</td>
<td>76 (68°F)</td>
<td>1.27</td>
<td>&lt; 1.00</td>
</tr>
</tbody>
</table>

Sure Klean\textsuperscript{\textregistered} Limestone Restorer

<table>
<thead>
<tr>
<th>SPECIFIC GRAVITY</th>
<th>SOLUBILITY IN WATER</th>
<th>APPEARANCE AND ODOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.14</td>
<td>100%</td>
<td>Clear liquid to slight amber color, pungent odor</td>
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</tbody>
</table>

IV FIRE AND EXPLOSION HAZARD DATA

EMERGENCY OVERVIEW

Sure Klean\textsuperscript{\textregistered} Limestone Restorer is a slightly amber-colored liquid with an irritating pungent odor. The vapor and mist from this product may cause irritation of the respiratory tract, wear appropriate respiratory protection. Wear splash-proof chemical goggles when handling this product.

FLASH POINT (METHOD): None

FLAMMABLE LIMITS: Unknown

EXTINGUISHING MEDIA: Any media appropriate for surrounding the type of fire involving this product.

SPECIAL FIRE FIGHTING PROCEDURES: Wear NIOSH/MSHA approved self-contained breathing apparatus with a full face piece operated in pressure demand or other positive pressure mode and full body protective clothing when fighting fires. Water may be used to cool closed containers.

UNUSUAL FIRE AND EXPLOSION HAZARDS: Reacts with most metals to release hydrogen gas which can form explosive mixtures with air. Extinguish all nearby sources of ignition.

V HEALTH HAZARD DATA

PRIMARY ROUTES OF EXPOSURE: Inhalation, skin, eyes.
CARCINOGEN INFORMATION: Not listed (OSHA, IARC, NTP). No standard carcinogenicity studies for hydrogen chloride were identified. Two studies on rats were conducted to determine if hydrogen chloride increased the formation of nasal tumors or increased the carcinogenic potential of formaldehyde. In both studies the rats were exposed to 10-ppm hydrogen chloride, 6 hours per day, 5 days per week. One study lasted 84 weeks while the other lasted the animals' lifetime. Hydrogen chloride did not cause an increase in nasal tumors and did not increase the carcinogenicity of formaldehyde.

MEDICAL CONDITIONS AGGRAVATED BY OVEREXPOSURE: Asthma, bronchitis, emphysema, and other lung conditions; and chronic nose, sinus, or throat conditions. Exposures of 100 ppm for six hours a day for 50 days caused only slight unrest and irritation to the eyes and nose of rabbits, guinea pigs and pigeons. The hemoglobin content of the blood was also slightly diminished. Monkeys receiving 20 exposures of 33 ppm for six hours did not display any adverse effects. Higher exposures (unspecified) have caused weight loss which paralleled the severity of exposure. Baboons exposed to 500, 5000 or 10,000 ppm for 15 minutes did not have significant alterations in any pulmonary function parameters 3 days or 3 months after exposure. In humans long term overexposure has been associated with erosion of the teeth.

EFFECTS OF OVEREXPOSURE: Causes severe damage to eyes and even blindness very rapidly. Causes burns, possible deep ulceration to skin. Breathing of mist or dust can cause damage to nasal and respiratory passages. Swallowing results in severe damage to mucous membranes and deep tissue; can result in death on penetration to vital areas. Glycolic Acid has been reported to cause kidney and liver damage in experimental animals from inhalation or ingestion.

EYE CONTACT: Liquid or concentrated vapors can cause eye irritation, severe burns and permanent damage including blindness even after a short exposure to small amounts.

SKIN CONTACT: Liquid or concentrated vapors can rapidly cause burning of skin. Repeated or prolonged contact with dilute solutions and concentrated vapors can cause irritation and dermatitis.

INHALATION: Hydrogen chloride gas, mist, and vapor can cause irritation of respiratory tract, with burning, choking, coughing, headaches, and rapid heartbeat. 35 ppm can cause irritation of the throat and 50-100 ppm is nearly unbearable for one hour. Inflammation, destruction of nasal passages and breathing difficulties can occur with high concentrations and may be delayed in onset. Inhalation of sufficiently high concentrations may result in laryngeal spasms, laryngeal edema or rapidly developing pulmonary edema. Mists may also cause bleeding of the nose and gums, and ulceration of the nasal or oral mucosa. 1,000-2,000 ppm can be fatal.

INGESTION: Unlikely route of exposure. Can cause severe burns of mouth, esophagus, and stomach. Nausea, pain, and vomiting may occur. Depending on the amount swallowed, holes may develop in the intestinal tract, kidney inflammation, shock and death can occur.

EMERGENCY AND FIRST AID PROCEDURES:

EYE CONTACT: Rinse eyes with large quantities of water for at least 15 minutes, holding eyelids apart to ensure flushing of the entire eye surface. Get medical attention immediately.

SKIN CONTACT: Remove contaminated clothing and flush exposed area with large quantities of water for at least 15 minutes. Launder contaminated clothing before reuse. Discard contaminated shoes. Get immediate medical attention.

INHALATION: Remove person to fresh air. If breathing stops, administer artificial respiration, preferably mouth-to-mouth. If breathing is difficult, give oxygen. Get medical attention immediately.

INGESTION: If conscious, give large quantities of water or milk. Do not induce vomiting. Get medical attention immediately. Do not give anything by mouth to an unconscious or convulsing person.

VI REACTIVITY DATA

STABILITY: Stable

CONDITIONS TO AVOID: Contact with strong bases (alkali), can cause violent reaction generating large amounts of heat.

INCOMPATIBILITY (MATERIALS TO AVOID): Metals, oxidizing agents, nitric acid, chlorates, sulfides, and cyanides. Contact with sulfides releases poisonous flammable hydrogen sulfide. Mercuric sulfate, perchloric acid, carbides of calcium, cesium, rubidium, acetylides of cesium and rubidium, phosphides of calcium and uranium, and lithium silicide.

Hydrogen Chloride can react with cyanide, forming lethal concentrations of hydrocyanic acid. Do not enter confined spaces such as tanks or pits without proper entry procedures as required by 29 CFR 1910.146.

HAZARDOUS COMBUSTION OR DECOMPOSITION PRODUCTS: Hydrogen gas when contacting metals, hydrogen chloride, carbon monoxide and carbon dioxide. Hydrogen gas generation has the highest potential for harm in confined or poorly ventilated areas where concentrations can approach flammable or explosive concentrations.

VII SPILL OR LEAK PROCEDURES
SPILL, LEAK, WASTE DISPOSAL PROCEDURES: Evacuate immediate area where concentrated fumes are present. Cleanup personnel must wear proper protective equipment. Provide adequate ventilation. Completely contain spilled material with dikes, etc., and prevent runoff into ground and surface waters or into sewers.

Dilution with water will decrease the fumes generated from spilled product. Spills and leaks should be neutralized by pouring dry soda ash or lime over the affected area. Concentrated product should be diluted with water before adding neutralizing agents to keep splattering and fumes to a minimum. Approximately 2.5 pounds of lime are required to neutralize one gallon of this product. Allow powdered material to remain on spill for five to ten minutes and flush thoroughly with water. Neutralized material, both liquid and solid, should be recovered for proper disposal.

WASTE DISPOSAL METHODS: Recovered solids or liquids may be disposed of in a permitted waste management facility. Neutralized materials may be discharged to a sanitary sewer with approval of the receiving treatment plant. Typical pH range of 6-10 is generally considered appropriate for discharge. Consult federal, state, and/or local authorities for approved procedure. For additional information regarding handling and disposal of rinse-water, please review Technical Bulletin 200-CW "Controlled Handling of Cleaning Wastewater". Empty containers must be triple rinsed before disposal in a permitted sanitary landfill. Check local restrictions.

VIII SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION: For vapor or mist concentrations which exceed or are likely to exceed 5 ppm Threshold Limit Value (TLV), wear a NIOSH/MSHA approved half-mask respirator with acid gas cartridges. NIOSH/MSHA approved self-contained breathing apparatus (SCBA) or pressure demand supplied air respirator with full face piece should be worn when concentrations exceed 50 ppm. A SCBA is recommended by NIOSH during leaks and/or emergencies. Follow all applicable respiratory use standards or regulations.

VENTILATION: Provide sufficient general and/or local exhaust ventilation to maintain exposure below the TLV.

PROTECTIVE CLOTHING: Wear neoprene or PVC rain suit. (Consult safety equipment supplier.)

PROTECTIVE GLOVES: Rubber type, neoprene or PVC with acceptable acid resistance. (Contact safety equipment supplier for approved gloves.)

EYE PROTECTION: Chemical splash goggles and/or full face shield (8 inch minimum) in compliance with OSHA regulations. Do not wear contact lenses because they may contribute to the severity of an eye injury.

OTHER PROTECTIVE EQUIPMENT: Acid-resistant rubber boots, headgear. Eyewash and safety shower.

IX SPECIAL PRECAUTIONS

WORK PRACTICES: Proper work practices and planning should be utilized to avoid contact with workers, passersby, and non-masonry surfaces. Brush on or apply at the lowest practical pressure. Do not atomize during application. Application equipment, scaffolding, swing stages and support systems must be constructed of acid resistant materials. Beware of wind drift. Wind-drift hazards may be diminished by pre-rinsing with low pressure water before pressure washing. Divert pedestrian traffic around work areas. See the Product Data sheet and label for specific precautions to be taken during use. Smoking, eating and drinking should be discouraged during the use of this product. Wash hands after handling or use.

This product is only to be used as supplied and specified. Do not alter, mix with chlorine-type bleaches or other chemicals, or dilute product except as specified on the label and Product Data sheet.

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: Use proper safety equipment (see section VIII) when handling. Store in a cool, well-ventilated area. Separate from oxidizing agents, nitric acid, alkalies, chlorates, sulfides, etc. (see section VI). Do not remove product label. Material diluted for application must be properly labeled and stored in acid-resistant containers such as rubber-lined steel or plastic.

Addition of acidic cleaner to water releases heat which can result in violent boiling and spattering. Always add cleaner to water slowly and in small amounts. Never use hot water. Never add water to acidic cleaners.

Containers of this material may be hazardous when emptied, since emptied containers retain product residues (vapor, liquid, and/or solid). All hazard precautions given in this data sheet must be observed.

OTHER PRECAUTIONS: Do not get in eyes, on skin or on clothing. Can cause severe injury or blindness. Avoid breathing mist or vapor. Provide ventilation sufficient to limit employee exposure below OSHA permissible limit. Do not take internally. Wash thoroughly after handling.

X REGULATORY INFORMATION
SHIPPING: This product carries the shipping description “UN1760, Corrosive Liquid, N.O.S. (Hydrochloric And Hydroxyacetic Acid), B, II” for shipping by ground, air and ocean transport. The product meets applicable DOT and UN standards when shipped in the original, unopened factory packaging, although container size may be limited for air transport. Some parcel shipping companies may limit container sizes.

NATIONAL MOTOR FREIGHT CLASSIFICATION: 44157 Sub 3 Rate Class: 85

SARA 313 REPORTABLE:

<table>
<thead>
<tr>
<th>CHEMICAL NAME</th>
<th>CAS</th>
<th>UPPERBOUND CONCENTRATION % BY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen Chloride</td>
<td>7647-01-0</td>
<td>30 %</td>
</tr>
</tbody>
</table>

CALIFORNIA PROPOSITION 65: This product contains no chemicals listed under California’s Proposition 65.

XI OTHER

MSDS Status: Date of Revision: December 20, 2013
For Product Manufactured After: N/A – No product reformulation
Changes: Document date brought current for Canadian customer due to regulatory requirements
Item #: 20034
Approved By: Regulatory Department

DISCLAIMER:

The information contained on the Material Safety Data Sheet has been compiled from data considered accurate. This data is believed to be reliable, but it must be pointed out that values for certain properties are known to vary from source to source. PROSOCO, Inc. expressly disclaims any warranty express or implied as well as any liability for any injury or loss arising from the use of this information or the materials described. This data is not to be construed as absolutely complete since additional data may be desirable when particular conditions or circumstances exist. It is the responsibility of the user to determine the best precautions necessary for the safe handling and use of this product for his unique application. This data relates only to the specific material designated and is not to be used in combination with any other material. Many federal and state regulations pertain directly or indirectly to the product's end use and disposal of containers and unused material. It is the purchaser's responsibility to familiarize himself with all applicable regulations.

DATE OF PREPARATION: December 10, 2013
**OVERVIEW**

Enviro Klean® ReKlaim safely removes biological and atmospheric staining from vertical or horizontal masonry surfaces. Cleans difficult mold and mildew staining that blackens limestone, marble, concrete and other masonry surfaces in humid environments.

The two-component ReKlaim system includes a liquid cleaner and a liquid activator. Treated surfaces are neutralized with a solution of Sure Klean® Limestone & Masonry Afterwash diluted 1:1 with clean water. Effectively removes light-to-severe staining without damage to the surface or the environment caused by more conventional cleaning methods.

**SPECIFICATIONS**

For all PROSOCO product specifications visit www.prosoco.com.

**ADVANTAGES**

- Removes mold and mildew staining, and light to heavy atmospheric soiling from masonry and wood.
- Will not damage masonry when properly used.
- Easy to apply with brush, roller or spray.
- Liquid formulation allows for fast and easy mixing.

**Limitations**

- Do not apply at temperatures below 40°F (4°C).
- On concrete and architectural concrete block, repeated applications may result in surface etching.
- Metal surfaces must be protected from exposure to cleaning solution.
- Not for use on polished marble, travertine or limestone.
- Suitable for use on wood and some painted surfaces. ALWAYS TEST.

**REGULATORY COMPLIANCE**

**VOC Compliance**

Enviro Klean® ReKlaim is compliant with all national, state and district regulations.

---

**TYPICAL TECHNICAL DATA**

<table>
<thead>
<tr>
<th>FORM</th>
<th>Cleaner: light yellow liquid</th>
<th>Activator: clear liquid</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPECIFIC GRAVITY</td>
<td>Cleaner: 1.09</td>
<td>Activator: 1.10</td>
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<tr>
<td>pH</td>
<td>Cleaner: 13.7</td>
<td>Activator: 2.40</td>
</tr>
<tr>
<td>WT/GAL</td>
<td>Cleaner: 9.10 lbs</td>
<td>Activator: 9.57 lbs</td>
</tr>
<tr>
<td>ACTIVE CONTENT</td>
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<td></td>
</tr>
<tr>
<td>TOTAL SOLIDS</td>
<td>Not applicable</td>
<td></td>
</tr>
<tr>
<td>VOC CONTENT</td>
<td>Not applicable</td>
<td></td>
</tr>
<tr>
<td>FLASH POINT</td>
<td>Cleaner: &gt;200°F (≥93°C)</td>
<td>Activator: not applicable</td>
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<tr>
<td>FREEZE POINT</td>
<td>Cleaner: 14°F (−10°C)</td>
<td>Activator: not applicable</td>
</tr>
<tr>
<td>SHELF LIFE</td>
<td>1 year in tightly sealed, unopened container</td>
<td></td>
</tr>
</tbody>
</table>
ReKlaim

PREPARATION

Protect people, vehicles, property, plants, metal and all non-masonry and acid-sensitive surfaces from cleaner, rinse, residue, fumes and wind drift. Protect and/or divert auto and pedestrian traffic.

Surface and Air Temperatures

Cleaning effectiveness is reduced when surface and air temperatures fall below 50°F (10°C). Do not apply at temperatures below 40°F (4°C). If freezing conditions exist prior to application, let masonry thaw.

Equipment

Apply using a synthetic roller, soft-bristled brush or spray applicator. Rinse with enough water and pressure to flush spent cleaner and dissolved soiling from the masonry surface and surface pores without damage. Inadequate rinsing leaves residues which may stain the cleaned surface.

Masonry-washing equipment generating 400–1000 psi with a water flow rate of 6–8 gallons per minute is the best water/pressure combination for rinsing porous masonry. Use a 15–45° fan spray tip. Heated water (150–180°F; 65–82°C) may improve cleaning efficiency.

Use adjustable equipment for reducing water flow rates and rinsing pressure as needed for sensitive surfaces. Rinsing pressures greater than 1000 psi and fan spray tips smaller than 15° may permanently damage sensitive masonry. Water flow rates less than 6 gpm may reduce cleaning productivity and contribute to uneven cleaning results.

Storage and Handling

Store in a cool, dry place with adequate ventilation. Always seal container after dispensing. Do not store or mix with other chemicals. Published shelf life assumes upright storage of factory-sealed containers in a dry place. Maintain temperature of 45–100°F (7–38°C). Do not double stack pallets. Dispose of unused product and container in accordance with local, state and federal regulations.

APPLICATION

Before use, read “Preparation” and “Safety Information.”

ALWAYS TEST each type of surface and each type of stain for suitability and desired results before overall application. Test using the following application instructions. Let test dry thoroughly before inspection and approval.

Mixing Instructions

ReKlaim

For 5-gallons of prepared solution, add 3 gallons clean water to a plastic container. Carefully add one gallon ReKlaim cleaner, followed by one gallon ReKlaim activator. Stir thoroughly with a nonmetallic tool. NOTE: Prepared solutions must be used immediately.

Limestone & Masonry Afterwash

Add 1 part clean water to a plastic container. Carefully add 1 part Limestone & Masonry Afterwash to the clean water. Never pour water into cleaner.

Coverage Rates

- Porous Surfaces:
  85–125 sq.ft. / 8–12 sq.m.
- Semi-Porous Surfaces:
  85–150 sq.ft. / 8–14 sq.m.
- Non-Porous Surfaces:
  85–200 sq.ft. / 8–19 sq.m.

Cleanup

Clean tools and equipment using fresh water.
**SAFETY INFORMATION**

**Enviro Klean® ReKlaim Cleaner**
Enviro Klean® ReKlaim Cleaner is an alkaline product and has safety issues common to corrosive materials. Use appropriate safety equipment and job site controls during handling and application. Read the full label and MSDS for precautionary instructions before use.

**First Aid**
**Ingestion:** If conscious, give large amounts of milk or water and call a physician, emergency room or poison control center immediately. Do not induce vomiting.

**Eye Contact:** Rinse eyes thoroughly for 15 minutes while lifting eyelids to assure thorough cleaning. Get immediate medical assistance.

**Skin Contact:** Remove contaminated clothing and rinse thoroughly for 15 minutes. Get medical attention as needed. Launder contaminated clothing before reuse.

**Inhalation:** Remove to fresh air. Give artificial respiration if not breathing. Get immediate medical attention.

**24-Hour Emergency Information:** INFOTRAC at 800-535-5053

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**SAFETY INFORMATION**

**Enviro Klean® ReKlaim Activator**
Enviro Klean® ReKlaim Activator is an oxidizer with corrosive characteristics. Use only as directed. Use appropriate safety equipment and job site controls during handling and application. Read the full label and MSDS for precautionary instructions before use.

**First Aid**
**Ingestion:** If conscious, give large amounts of water and call a physician, emergency room or poison control center immediately. Do not induce vomiting.

**Eye Contact:** Rinse eyes thoroughly for 15 minutes. Get immediate medical assistance.

**Skin Contact:** Remove contaminated clothing and rinse thoroughly for 15 minutes. Get medical attention. Launder contaminated clothing before reuse.

**Inhalation:** Remove to fresh air. Get artificial respiration if not breathing. Get immediate medical attention.

**24-Hour Emergency Information:** INFOTRAC at 800-535-5053

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**BEST PRACTICES**

To avoid streaking, keep wall surfaces immediately below area being cleaned running wet and free of cleaner rundown and residues.

Masonry-washing equipment generating 400—1000 psi with a water flow rate of 6—8 gallons per minute is the best water/pressure combination for rinsing porous masonry. Use a 15—45° fan spray tip. Heated water (150—180°F; 65—82°C) may improve cleaning efficiency.

Repeated applications to concrete or architectural concrete block may result in surface etching.

Prepared ReKlaim solutions must be used immediately.

Never go it alone. For problems or questions, contact your local PROSOCO distributor or field representative. Or call PROSOCO technical Customer Care toll-free at 800-255-4255.
WARRANTY

The information and recommendations made are based on our own research and the research of others, and are believed to be accurate. However, no guarantee of their accuracy is made because we cannot cover every possible application of our products, nor anticipate every variation encountered in masonry surfaces, job conditions and methods used. The purchasers shall make their own tests to determine the suitability of such products for a particular purpose.

PROSOCO Inc. warrants this product to be free from defects. Where permitted by law, PROSOCO makes no other warranties with respect to this product, express or implied, including without limitation the implied warranties of merchantability or fitness for particular purpose. The purchaser shall be responsible to make his own tests to determine the suitability of this product for his particular purpose. PROSOCO's liability shall be limited in all events to supplying sufficient product to re-treat the specific areas to which defective product has been applied. Acceptance and use of this product absolves PROSOCO from any other liability, from whatever source, including liability for incidental, consequential or resultant damages whether due to breach of warranty, negligence or strict liability. This warranty may not be modified or extended by representatives of PROSOCO, its distributors or dealers.

CUSTOMER CARE

Factory personnel are available for product, environment and job-safety assistance with no obligation. Call 800-255-4255 and ask for Customer Care - technical support.

Factory-trained representatives are established in principal cities throughout the continental United States. Call Customer Care at 800-255-4255, or visit our web site at www.prosoco.com, for the name of the Enviro Klean® representative in your area.
MATERIAL SAFETY DATA SHEET
PROSOCO, Inc.

I PRODUCT IDENTIFICATION

MANUFACTURER'S NAME
AND ADDRESS: PROSOCO, Inc.
3741 Greenway Circle
Lawrence, KS 66046

EMERGENCY TELEPHONE NUMBERS:
8:00 AM – 5:00 PM CST Monday-Friday:
785-865-4200
NON-BUSINESS HOURS (INFOTRAC): 800/535-5053

PRODUCT TRADE NAME: Enviro Klean® ReKlaim Cleaner

II HAZARDOUS INGREDIENTS

CHEMICAL NAME
(SODIUM HYDROXIDE) 1310-73-2
(CAS NO.) 68478-65-9
FACTOR CODE
3,0,1,-
2,0,-
NOT ESTABLISHED

ACGIH TLV/TWA
2mg/m³
OHSA PEL/TWA
2mg/m³

Percent content of hazardous ingredients withheld as trade secret pursuant to OSHA regulations.

III PHYSICAL DATA

BOILING POINT
(SODIUM HYDROXIDE) 145°C
(CAUSTIC SODA) 6.33 (40°C)
(AMINE OXIDE) 90.0 (100 °F)

VAPOR PRESSURE
SPECIFIC GRAVITY
1.09
pH
13.7

VAPOR DENSITY
(Air = 1)
SOLUBILITY
IN WATER
100%

EVAPORATION RATE
(BUTYL ACETATE = 1)
APPEARANCE AND
ODOR
Light yellow liquid,
soapy odor

IV FIRE AND EXPLOSION HAZARD DATA

EMERGENCY OVERVIEW

Enviro Klean® ReKlaim Cleaner is a corrosive, caustic material. Prevent skin, eye and respiratory contact. Exposed areas must be rinsed immediately with large quantities of water. May react violently when in contact with strong acids.

FLASH POINT (METHOD): None.

FLAMMABLE LIMITS: Not applicable.

EXTINGUISHING MEDIA: Use water spray to cool fire exposed surfaces and to protect personnel. Use media appropriate for surrounding fire.

SPECIAL FIRE FIGHTING PROCEDURES: Use NIOSH/MSHA approved self-contained breathing apparatus where this material is involved in a fire.

UNUSUAL FIRE AND EXPLOSION HAZARDS: Can react with metals such as aluminum, magnesium, copper, zinc, tin, brass or bronze, to generate hydrogen gas, which is flammable and/or explosive if ignited. Avoid contact with leather, wool, acids, organic halogen compounds, or organic nitro compounds.

V HEALTH HAZARD DATA

PRIMARY ROUTES OF EXPOSURE: Skin, eyes, ingestion.
CARCINOGEN INFORMATION: Not listed (OSHA, IARC, NTP)

MEDICAL CONDITIONS AGGRAVATED BY OVEREXPOSURE: No applicable information found.

EFFECTS OF OVEREXPOSURE: Corrosion of exposed tissues resulting in burns and frequently deep ulcerations.

EYE CONTACT: Can cause severe damage and even blindness very rapidly. Small quantities can result in permanent damage and/or loss of vision.

SKIN CONTACT: Causes severe burns, possible deep ulceration and scarring. Prolonged contact destroys tissue. Can cause irritant dermatitis. Onset of irritation from burns may be delayed for minutes in the case of contact with concentrated product or hours for contact with product diluted by rinse water.

INHALATION: Mists are very irritating to upper respiratory tract. Can cause tissue damage to upper respiratory tract. Can cause pneumoconiosis, including fibrosis.

INGESTION: Results in severe damage to mucous membranes and deep tissues; can result in death on penetration to vital areas.

EMERGENCY AND FIRST AID PROCEDURES:

EYE CONTACT: Immediately flush exposed area with water for at least 30 minutes, holding eyelids apart to ensure flushing of the entire eye surface. Get immediate medical attention. If physician is not immediately available, continue flushing with water. Do not use chemical antidote. Washing eyes within seconds is essential to achieve maximum effectiveness.

SKIN CONTACT: Immediately flush exposed area with water for at least 30 minutes. Presence of a slippery residue indicates that some caustic still remains. Get medical attention. Remove contaminated clothing. Launder contaminated clothing before reuse. Discard contaminated shoes.

INHALATION: Remove to fresh air. If not breathing, give artificial respiration, preferably mouth-to-mouth by a trained person. If breathing is difficult, give oxygen. Get medical attention.

INGESTION: DO NOT INDUCE VOMITING! Dilute by giving large amounts of water or milk if immediately available. Give milk of magnesia. If person is unconscious, do not give anything by mouth. Get medical attention immediately.

NOTE TO PHYSICIAN:

EYES: May cause severe corneal injury or burn. May cause impairment of vision. Stain for evidence of corneal injury. If cornea is burned, instill antibiotic steroid preparation frequently. Consult ophthalmologist.

SKIN: May cause severe burn. If burn is present, treat as any thermal burn.

RESPIRATORY: May cause severe irritation. Administer oxygen if available. Bronchodilator, expectorants, and antitussives may be of help. (Tracheal and/or esophagoscopic control.)

GENERAL: Consult standard literature. Treatment should be based on the sound judgment of the physician and the individual reactions of the patient. Treat for clinical symptoms.

VI REACTIVITY DATA

STABILITY: Stable.

CONDITIONS TO AVOID: Strong acids.

INCOMPATIBILITY (MATERIALS TO AVOID): Organic materials, concentrated acids, metals such as aluminum, magnesium, zinc, tin, chromium, brass, bronze, or copper. Food, sugars, leather, and wool.

HAZARDOUS COMBUSTION OR DECOMPOSITION PRODUCTS: Contact with reactive metals will generate hydrogen gas, which is flammable and/or explosive. Contact with various food sugars may form carbon monoxide.

VII SPILL OR LEAK PROCEDURES

SPILL, LEAK, WASTE DISPOSAL PROCEDURES: Wear appropriate NIOSH/MSHA approved respirator and other protective safety equipment. Dike area to contain the spill. Dilute the spill with large amounts of water, then neutralize with dilute acid. A vacuum truck or corrosion resistance wet-vac may be used to pick up large quantities of neutralized residual material for disposal. After all visible traces have been removed; flush the area with large amounts of water.

WASTE DISPOSAL METHODS: Dispose of in a manner approved for this material or in an approved hazardous waste facility. Neutralized materials may be discharged to a sanitary sewer with approval of the receiving treatment plant. Typical pH range of 6-10 is generally considered appropriate for discharge. Consult federal, state, and/or local authorities for approved procedure. For additional information regarding handling and disposal of rinse-water, please review Technical Bulletin 200-CW "Controlled Handling of Cleaning Wastewater". Empty containers must be triple rinsed before disposal in a permitted sanitary landfill. Check local restrictions.
VIII SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION: Evolution of airborne sodium hydroxide from this product is unlikely, except if atomized or applied to hot surfaces. NIOSH/MSHA approved respiratory protection required in the absence of proper environmental control. If air monitoring indicates that the concentration of sodium hydroxide exceeds the TLV, wear a NIOSH approved powered air-purifying or full-face cartridge type respirator with dust/mist cartridges. Respiratory protection program must be in accordance with 29 CFR 1910.134.

VENTILATION: Sufficient to maintain airborne concentrations below the Threshold Limit Values TLV(s).

PROTECTIVE CLOTHING: Wear protective clothing such as rubber boots, PVC clothing, and plastic headgear as required to prevent skin contact.

PROTECTIVE GLOVES: Alkali-resistant such as nitrile rubber, neoprene rubber, natural rubber, or PVC.

EYE PROTECTION: Close fitting chemical safety goggles and/or full face shield. Do not wear contact lenses because they may contribute to the severity of an eye injury.


IX SPECIAL PRECAUTIONS

WORK PRACTICES: Proper work practices and planning should be utilized to avoid contact with workers, passersby, and non-masonry surfaces. Do not atomize during application. Beware of wind drift. Wind drift hazards may be minimized by pre-rinsing product off of the substrate with low-pressure water immediately before pressure washing. See the Product Data sheet and label for specific precautions to be taken during use. Smoking, eating and drinking should be prohibited during the use of this product. Wash hands before breaks and at the end of a shift.

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: Wear appropriate safety equipment and clothing. Do not get in eyes, on skin, or on clothing. Do not take internally.

Avoid breathing mist. Store in a cool, dry, well-ventilated place. Separate from acids, explosives, organic peroxides, and easily ignitable materials.

Keep containers tightly closed when not dispensing product. Use care around spilled material because it will be slippery. Never touch eyes or face with hands or gloves that may be contaminated with this product. Treat empty containers as if they were full.

OTHER PRECAUTIONS: Do not get in eyes, on skin or on clothing. Can cause severe injury or blindness. Do not breathe mist. Do not take internally. Wash thoroughly after handling. Do not eat, drink, or smoke in work areas.

Comments: Hazardous carbon monoxide gas can form upon contact with food and beverage products in enclosed vessels and can cause death.

X REGULATORY INFORMATION

SHIPPING: The shipping description for this product is UN3266, Corrosive Liquid, Basic, Inorganic, N.O.S. (Sodium Hydroxide) 8, II when shipped via domestic or international ground or marine transport. This product and container combination is not allowed in air transport.

NATIONAL MOTOR FREIGHT CLASSIFICATION: NMFC #: 44157 Sub 3 Rate Class: 85

SARA 313 REPORTABLE:

CHEMICAL NAME

None

CAS

UPPERBOUND CONCENTRATION % BY WEIGHT

None

CALIFORNIA PROPOSITION 65: not applicable

XI OTHER

MSDS Status: Date of Revision: June 15, 2013

For Product Manufactured After: N/A – No product reformulation, only product name change

Changes: Product name change

Item #: 41040

Approved By: Regulatory Department
DISCLAIMER:
The information contained on the Material Safety Data Sheet has been compiled from data considered accurate. This data is believed to be reliable, but it must be pointed out that values for certain properties are known to vary from source to source. PROSOCO, Inc. expressly disclaims any warranty express or implied as well as any liability for any injury or loss arising from the use of this information or the materials described. This data is not to be construed as absolutely complete since additional data may be desirable when particular conditions or circumstances exist. It is the responsibility of the user to determine the best precautions necessary for the safe handling and use of this product for his unique application. This data relates only to the specific material designated and is not to be used in combination with any other material. Many federal and state regulations pertain directly or indirectly to the product's end use and disposal of containers and unused material. It is the purchaser's responsibility to familiarize himself with all applicable regulations.

DATE OF PREPARATION: June 15, 2013
I PRODUCT IDENTIFICATION

MANUFACTURER'S NAME AND ADDRESS: PROSOCO, Inc.
3741 Greenway Circle
Lawrence, KS 66046

EMERGENCY TELEPHONE NUMBERS:
8:00 AM – 5:00 PM CST Monday-Friday: 785/865-4200
NON-BUSINESS HOURS (INFOTRAC): 800/535-5053

PRODUCT TRADE NAME: Enviro Klean® ReKlaim Activator

II HAZARDOUS INGREDIENTS

<table>
<thead>
<tr>
<th>CHEMICAL NAME</th>
<th>(COMMON NAME)</th>
<th>CAS NO.</th>
<th>NFPA CODE</th>
<th>ACGIH TLV/TWA</th>
<th>OSHA PEL/TWA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen Peroxide</td>
<td>(Hydrogen Peroxide)</td>
<td>7722-84-1</td>
<td>2,0,1,0X</td>
<td>1 ppm</td>
<td>1 ppm</td>
</tr>
</tbody>
</table>

III PHYSICAL DATA

<table>
<thead>
<tr>
<th></th>
<th>BOILING POINT (°F)</th>
<th>VAPOR PRESSURE (mm Hg)</th>
<th>VAPOR DENSITY (Air = 1)</th>
<th>EVAPORATION RATE (Butyl Acetate = 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen Peroxide</td>
<td>212°F (100°C)</td>
<td>23.0 @ 20°C (68°F)</td>
<td>Not applicable</td>
<td>&gt;1</td>
</tr>
<tr>
<td>Enviro Klean® ReKlaim Activator</td>
<td>1.1</td>
<td>Specific Gravity</td>
<td>Solubility in Water</td>
<td>Appearance and Odor</td>
</tr>
</tbody>
</table>

IV FIRE AND EXPLOSION HAZARD DATA

EMERGENCY OVERVIEW

Danger! Enviro Klean® ReKlaim Activator is a strong oxidizer. Contact with other material may cause fire. Corrosive. Causes burns to skin, eyes, and respiratory tract. Harmful if swallowed or inhaled.

FLASH POINT (METHOD): Not combustible, but substance is a strong oxidizer and its heat of reaction with reducing agents or combustibles may cause ignition. Increases the flammability of combustible, organic and readily oxidizable materials.

EXPLOSION: Contact with oxidizable substances may cause extremely violent combustion. Drying of concentrated hydrogen peroxide on clothing or other combustible materials may cause fire or explosion. Sealed containers may rupture when heated.

EXTINGUISHING MEDIA: Water spray may be used to extinguish surrounding fire and cool exposed containers. Water spray will also reduce fume and irritant gases.

SPECIAL FIRE FIGHTING PROCEDURES: In the event of a fire, wear full protective clothing and NIOSH-approved self-contained breathing apparatus with full facepiece operated in the pressure demand or other positive pressure mode.

UNUSUAL FIRE AND EXPLOSION HAZARDS: May intensify a fire; greater hazard at elevated temperature.

V HEALTH HAZARD DATA

PRIMARY ROUTES OF EXPOSURE: Skin, eyes, inhalation, ingestion.

CARCINOGEN INFORMATION: Not listed (OSHA, IARC, NTP)

MEDICAL CONDITIONS AGGRAVATED BY OVEREXPOSURE: Persons with pre-existing skin disorders or eye problems or impaired respiratory function may be more susceptible to the effects of the substance.
EFFECTS OF OVEREXPOSURE: No information found

EYE CONTACT: Vapors are very corrosive and irritating to the eyes. Symptoms include pain, redness, and blurred vision. Splashes can cause permanent tissue destruction.

SKIN CONTACT: Corrosive. Symptoms of redness, pain, and severe burn can occur. If left on skin for long period, blisters may form.

INHALATION: Vapors are corrosive and irritating to the respiratory tract. Inhalation of mist may burn the mucous membrane of the nose and throat. In severe cases, exposures may result in pulmonary edema and death.

INGESTION: Corrosive and irritating to the mouth, throat, and abdomen. Large doses may cause symptoms of abdominal pain, vomiting, and diarrhea as well as blistering or tissue destruction. Stomach distention (due to rapid liberation of oxygen), and risk of stomach perforation, convulsions, pulmonary edema, coma, possible cerebral edema (fluid on the brain), and death are possible.

EMERGENCY AND FIRST AID PROCEDURES:

EYE CONTACT: Immediately flush eyes with plenty of water for at least 15 minutes, lifting lower and upper eyelids occasionally. Get medical attention immediately.

SKIN CONTACT: Immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Get medical attention immediately. Wash clothing before reuse. Thoroughly clean shoes before reuse. If allowed to dry on clothing, evaporation leads to concentration and increased possibility of ignition.

INHALATION: Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention immediately.

INGESTION: If swallowed, DO NOT INDUCE VOMITING. Give large quantities of water. Never give anything by mouth to an unconscious person. Get medical attention immediately.

VI REACTIVITY DATA

STABILITY: Normally stable if uncontaminated, but slowly decomposes to release oxygen. Unstable with heat, may result in dangerous pressures. A strong oxidizer, reacts violently upon contact with many organic substances, particularly textile and paper. Avoid light and keep in a closed but vented container to prevent evaporation (concentration) and contamination.

CONDITIONS TO AVOID: Light and incompatibles. Avoid excess heat and contact with combustible or organic materials.

INCOMPATIBILITY (MATERIALS TO AVOID): Heat, reducing agents, organic materials, dirt, alkalis, rust, and many metals. Spontaneous combustion may occur on standing in contact with readily flammable materials.

HAZARDOUS COMBUSTION OR DECOMPOSITION PRODUCTS: Decomposes to water and oxygen with rapid heat release. Use vented containers. The solution can decompose violently upon heating.

VII SPILL OR LEAK PROCEDURES

SPILL, LEAK, WASTE DISPOSAL PROCEDURES: CAUTION! Corrosive material. Causes fires with organic material. Do not use absorbents that can be oxidized. Ventilate area of leak or spill. Wear appropriate personal protective equipment as specified in Section 8. Contain and recover liquid when possible. Do not return spilled material to original container. Larger Spills: Dilute with a large amount of water and hold in a pond or diked area until the peroxide decomposes followed by discharge into a suitable treatment system. May be neutralized with sodium metabisulfite or sodium sulfite after diluting to 5-10% peroxide. Do not flush undiluted material to sewer. This oxidizing material can increase the flammability of adjacent combustible materials. Empty containers should be rinsed with water before discarding.

WASTE DISPOSAL METHODS: Product as supplied is classified as a hazardous waste. Once diluted and fully decomposed, hydrogen peroxide is not classified as a hazardous waste. Waste management options depend on the properties of the product and rinsewater generated during use. Empty container may be rinsed with water and disposed in a licensed sanitary landfill. Check local restrictions. Dispose of container and unused contents in accordance with federal, state and local requirements.

VIII SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION: If the exposure limit is exceeded, wear a supplied air, full-face piece respirator, airlined hood, or full-face piece self-contained breathing apparatus. This substance has unknown warning properties. When mixed with ReKlaim Cleaner component the concentration of hydrogen peroxide and tendency to form vapors will be greatly decreased.

VENTILATION: A system of local and/or general exhaust is recommended to keep employee exposures below the Airborne Exposure Limits. Local exhaust ventilation is generally preferred because it can control the emissions of the contaminant at its source, preventing dispersion of it into the general work area.
PROTECTIVE CLOTHING: Rubber, Neoprene or equivalent

PROTECTIVE GLOVES: Rubber, Neoprene or equivalent

EYE PROTECTION: Use chemical safety goggles and/or a full face shield when handling product.

IX SPECIAL PRECAUTIONS

WORK PRACTICES: Proper work practices and planning should be utilized to avoid contact with workers, passersby, and non-masonry surfaces. Do not atomize during application. Beware of wind drift. Always follow published dilution instructions. See the Product Data sheet and label for specific precautions to be taken during use. Smoking, eating and drinking should be prohibited during the use of this product. Wash hands before breaks and at the end of a shift.

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: Vent all containers to prevent pressure buildup; keep upright. Store in a cool, ventilated, non-combustible area remote from combustible, organic, readily oxidizable materials and catalytic metals; protect from physical damage. Do not breathe vapor. Do not get in eyes, on skin, or on clothing. Retained residue may make empty containers hazardous; use caution! Never return unused Hydrogen Peroxide to original container.

X REGULATORY INFORMATION

SHIPPING: This product carries the proper shipping description UN2984, Hydrogen Peroxide, Aqueous Solution, 5.1, III in domestic or international shipments. Container sizes 1-gallon and smaller are reclassified as Consumer Commodity ORM-D for domestic ground shipment. Some container sizes are restricted in air transport.

NATIONAL MOTOR FREIGHT CLASSIFICATION: NMFC #: 48580 Sub 3 Class: 55

SARA 313 REPORTABLE:

CHEMICAL NAME CAS UPPERBOUND CONCENTRATION % BY WEIGHT
N/A
CALIFORNIA PROPOSITION 65: Contains no chemicals listed under California’s Proposition 65.

XI OTHER

MSDS Status: Date of Revision: June 15, 2013
For Product Manufactured After: N/A – product renamed, but no formulary changes made
Changes: Product Name Change
Item #: 41042
Approved By: Regulatory Department

DISCLAIMER:

The information contained on the Material Safety Data Sheet has been compiled from data considered accurate. This data is believed to be reliable, but it must be pointed out that values for certain properties are known to vary from source to source. PROSOCO, Inc. expressly disclaims any warranty express or implied as well as any liability for any injury or loss arising from the use of this information or the materials described. This data is not to be construed as absolutely complete since additional data may be desirable when particular conditions or circumstances exist. It is the responsibility of the user to determine the best precautions necessary for the safe handling and use of this product for his unique application. This data relates only to the specific material designated and is not to be used in combination with any other material. Many federal and state regulations pertain directly or indirectly to the product’s end use and disposal of containers and unused material. It is the purchaser’s responsibility to familiarize himself with all applicable regulations.

DATE OF PREPARATION: June 15, 2013