CLEANING & CARING FOR LIMESTONE OBJECTS

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PREAMBLE

This guide describes good practices in limestone object cleaning. It outlines how limestone objects can deteriorate and it aids in the decision making on whether an object needs cleaning, to what extent, and what technique might be appropriate. The guide also gives advice for the storage and exhibition of limestone objects. Additionally, it includes information on where to get further help and support.

The guide is intended for those involved in or responsible for decision making about conservation activities, such as local authority staff, custodians, staff responsible for collections care, and staff overseeing volunteers.

A short practical version of this guide for those conducting limestone object cleaning is available in the appendix.

Image on front page showing architectural limestone features. Image courtesy of Dr. Emily Williams.

CLEANING & CARING FOR LIMESTONE OBJECTS

1. Introduction

1.1. What is Limestone?

Humans have utilised stone since the earliest times with the ancient Egyptians being the first people to quarry limestone in huge quantities for their pyramid constructions. Stone has always been considered a very important material and many quarries used to be in royal ownership.[1]

A **stone** is a piece of rock that has been detached from the Earth's crust. **Rocks** are aggregates of minerals and are typically clustered into three categories: igneous, sedimentary, and metamorphic.[2] Limestones belong to the sedimentary kind and make up about 28% of the Earth's surface.[3] **Sedimentary rocks** are the products that form when the Earth's surface is being exposed to the atmosphere, mainly to rainfalls and wind: The surface undergoes a weathering process where pre-existing rocks are physically disintegrated, transported (called erosion), and deposited in a new place.[4] Sedimentary rocks are built up in layers over thousands of years. While igneous and metamorphic rocks are usually hard and have a very low porosity, sedimentary rocks are comparably **soft** (i.e. they can be easier scratched) and can be quite **porous**.[5]

Limestones mainly consist of calcium carbonate in the form of the mineral **calcite**. They are formed either via direct precipitation of calcium carbonate from ground, rain, or sea water, or through fossilised shells of one or more organisms (the organisms use calcium carbonate from their habitat to build their shells or skeletons). Some limestones are created through the erosion of pre-existing limestones.[6]

Remember:
Although stones are said to be hard materials and your object may seem to be difficult to break, bend, or deform, it can still be soft and easily scratched.

[1] F.G. Dimes. 1998a. 'The nature of building and decorative stones'. In Ashurst, J. and Dimes, F.G. (eds.) *Conservation of Building and Decorative Stone*. Oxford: Butterworth-Heinemann: 19.
[2] Dimes 1998a: 22.
[3] F.G. Dimes. 1998b. 'Sedimentary rocks'. In Ashurst, J. and Dimes, F.G. (eds.) *Conservation of Building and Decorative Stone*. Oxford: Butterworth-Heinemann: 61.
[4] K.C. Beck. 2021. *Sedimentary rock*. Viewed 09. February 2021 <https://www.britannica.com/science/sedimentary-rock>.
[5] Madhu. 2011. *Difference Between Igneous Rocks and Sedimentary Rocks*. Viewed 09. February 2021 <https://www.differencebetween.com/difference-between-igneous-rocks-and-vs-sedimentary-rocks/#Sedimentary%20Rocks>.
[6] Dimes 1998b: 86ff.

1.2. What does Limestone look like?

Limestones can **vary greatly** in their appearance and properties depending on their provenance and composition. In its purest form, limestone is nearly white, but only few limestones consist entirely of calcium carbonate. Most contain other minerals and **inclusions** that influence their colour like clay, dolomite, quartz, or even mud. Occasionally iron minerals and pyrite may be present.[7] Limestones vary in colour from black, brown, orange, green to buff, cream, yellow, and white. Some may even be pinkish.[8] Limestones range from dense stones with low porosity to soft chalky and highly porous ones. They can be coarse or have a very fine texture.[9] With some experience, it is possible to differentiate a limestone from a sandstone (another form of sedimentary rock) which is important since specific treatment methods may be appropriate for one type of stone but not for the other. Limestones, for example, are susceptible to acidic substances. The exact provenance and composition, however, can only be determined through **laboratory-based tests** and **consultation with experienced geologists**.[10]

*The **treatment methods described in this guide can be used on all types of limestone** if properly executed. So, do not worry too much if you are unable to identify the exact stone type that your object is made of.*

Because limestone was readily available and relatively easy to quarry and to carve, it has been extensively used for building purposes.[11] Entire buildings, walls, or features can be made of limestone (like the Haddon Hall in Derbyshire, the walls of Cardiff Castle, the columns at Durham Cathedral, or various features at colleges in Cambridge).[12] But it has also been used widely for stone artefacts. Due to its softness, limestone was often carved and thus used for altars and inscription stones, gravestones, for statues, sculptures, monuments, and reliefs.[13]

Upon closer inspection – and often hiding under a layer of dust and soiling - the object may show **tool marks** or traces of **surface finishes** like paint and gilding (decoration with gold leaf or powder). A maker's mark may be carved into the stone. These are all important **evidence of the object's manufacturing process**: With a mason's axe the rough form of the object was cut out, and then further shaped using picks, punches, and points struck by hammer or mallet. Different sizes of tools were used. With flat chisels and drills, the stone was further refined, and designs and inscriptions were added. Further smoothing of the surface was accomplished using metal tools like rasps or riffles, and stone grit.[14] Stone objects may have been finished with a primer and painted over in various colours, or other types of coatings and additions like Plaster of Paris (a quick-setting gypsum plaster in fine powder-form that hardens when moistened and dried) may have been

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[7] Dimes 1998b: 89.
[8] N. Durnan. 2015. 'Chapter Nine: Limestone'. In Henry, A. (ed.) *Stone Conservation: Principles and Practice*. Abingdon: Routledge: 162.
[9] Durnan 2015: 162.
[10] F.G. Dimes. 1998c. 'Determination of a sample'. In Ashurst, J. and Dimes, F.G. (eds.) *Conservation of Building and Decorative Stone*. Oxford: Butterworth-Heinemann: 150f.
[11] New World Encyclopedia. n.d. *Uses of limestone*. Viewed 23. March 2021 <www.newworldencyclopedia.org/entry/Limestone#Uses_of_limestone>.
[12] Dimes 1998b: 90ff.
[13] British Museum. n.d. *Collection Search for: Place: Europe -> England, Material: Limestone*. Collection search conducted on 23. March 2021 <https://www.britishmuseum.org/collection/search?place=Europe&place=England&material=limestone&image=true&view=grid&sort=object_name__asc&page=1>.
[14] V&A. n.d. *Sculpture techniques*. Viewed 15. February 2021 <https://www.vam.ac.uk/articles/sculpture-techniques>.

added. Stone was often gilded or decorated with silver and other metals applied in leaf or powder form over a suitable priming.[15]

The object can also show other signs of "dirt" and inclusions that come from its **use life** or from **old repairs** (Plaster of Paris fills, metal pins, adhesives etc.). It is important to consider whether these are really harmful to the object, or whether their removal would also remove a part of the object's history.

Remember:
Beneath the dirt layer may be traces of the stone's history that must be preserved. Not all dirt is recent staining. Surface decorations may not have been as colourful as we would expect, so be careful not to miss anything.

1.3. How does Limestone Deteriorate?

It has been calculated that on average 1.5 to 3 millimetres of outdoor limestone erode every 100 years in temperature climates. This can cause inscriptions on tombstones and other surface decorations to vanish within 300 years in the UK.[16]

The main causes of deterioration are:

- Soluble Salts
- Air pollution
- Frost damage & Wind Erosion
- Biological Growth
- Museum Visitors
- Inappropriate (Past) Treatments
- Clay and mud inclusions in the stone that are susceptible to moisture

1.3.1. Soluble Salts

Together with air pollution, soluble salts are one of the main causes for deterioration, and **salt crystallisation** can be very damaging to porous stones like limestones.[17] Salts are transported to the pores and fissures by **water**. On outdoor stones this is usually rainwater, indoors the often hygroscopic (water-loving) salts attract moisture from the air. When the stone dries, the water evaporates, and the salts deposit either on the surface or within the stone. This is called *crystallisation*. With every cycle of wetting and subsequent drying the salts redissolve and recrystallise, often moving around inside the stone's pore system and increasing in volume. This causes **pressure** to be exerted on the pore walls within the stone. When the pressure exceeds the

[15] L.R. Rogers. n.d. *Sculpture*. Viewed 15. February 2021 <https://www.britannica.com/art/sculpture>.
[16] S. Scheerer. 2008. *Microbial biodeterioration of outdoor stone monuments. Assessment methods and control strategies.* PhD Thesis. Cardiff University. Ann Arbor: ProQuest LLC: 19.
[17] D.B. Honeyborne. 1998. 'Weathering and decay of masonry'. In Ashurst, J. and Dimes, F.G. (eds.) *Conservation of Building and Decorative Stone*. Oxford: Butterworth-Heinemann: 154.

strength of the stone, damage in the form of cracks, surface flaking and powdering can occur.[18] Salts can also damage the stone due to different rates of **thermal expansion**: At the same temperature, salts like sodium chloride expand much more than the calcite that makes up limestone causing internal stresses that again can result in cracks.[19]

Examples of stone features having experienced material loss (left), surface flaking/chipping (middle) and stone splitting (right). Images taken by author with kind permission from *Burwell Museum & Windmill*.

Once salts have been introduced to the stone, wet-cleaning as well as **changes in relative humidity and temperature** can often be sufficient to cause salt damage.[20] Salt contamination inside the pores can only be detected with certain laboratory-based tests, whereas salt growth on the stones' surface may be visible in the form of a white powder (called **efflorescence**). Efflorescence can be unaesthetic but is usually harmless[21] – at least on undecorated surfaces.

Stones are contaminated with soluble salts from several **sources**:[22]

- **Air pollution** can introduce sulphates and nitrates
- Rising damp can introduce salts from the **soil**
- Salts may be introduced during **burial** or historic **use lives** (e.g. salted meats have been stored in stone vessels during Medieval times)
- Near the **ocean**, sodium chloride may be blown in by the wind
- **De-icing** salts in winter
- Unsuitable **cleaning products** (caustic soda or caustic potash are often advertised for cleaning limestone but can be converted to sodium or potassium sulphates by acids in the air), garden **fertilisers** and so on

Remember:
Your object may contain harmful soluble salts even if you cannot see them. Humidity and water can cause damage – even months or years after its exposure.

[18] E. Doehne and C.A. Price. 2010. *Stone Conservation: An Overview of Current Research*. Los Angeles: The Getty Conservation Institute: 15.
[19] Western Australian Museum. 2017. *Stone and Geological Collections*. Viewed 16 February 2021. <https://manual.museum.wa.gov.au/conservation-and-care-collections-2017/stone-and-geological-collections>.
[20] J. Larson. 1998. 'The conservation of stone monuments in churches'. In Ashurst, J. and Dimes, F.G. (eds.) *Conservation of Building and Decorative Stone*. Oxford: Butterworth-Heinemann: 189.
[21] Honeyborne 1998: 154.
[22] Doehne & Price 2010: 15, Honeyborne 1998: 155.

1.3.2. Air Pollution

Factories, transportation, domestic heating systems, and other forms of human activity are the main causes that pollute our air with small carbon particles and sulphurous gases. When these gases combine with water, **acid rain** (sulphurous and sulphuric acids) is formed. This can react with calcium carbonate (the main constituent of limestone) to form partially soluble calcium sulphate dihydrate – also called **gypsum**. As water evaporates, the gypsum crystallises on the limestone's surface[23] slowing down the attack.[24] Where limestone objects are exposed to regular rainfalls, the gypsum is washed off leaving behind a fresh surface that anew can be attacked by acid rain. This process is called **sulphation**. With time, sulphation of limestone will erode the stone's surface.[25]

In sheltered areas, a transparent crust is formed. This is quickly polluted by atmospheric carbon particles forming a **black crust**. The crust may be very thin or accumulate to a thickness of several centimetres.[26] Blisters can form and burst, exposing fresh limestone to further acid attack, for example introduced in foggy weather.[27]

Remember:
Manually washing off the gypsum crust will expose fresh limestone to the atmosphere. Without shelter, the cycle will start anew gradually eroding your object.

1.3.3. Frost Damage & Wind Erosion

Frost damage is less common than deterioration caused by air pollution and salt crystallisation but can nonetheless be severe. It usually only happens when a **stone is very wet** or when water is caught and collected in **crevices**. Remember, a snow layer may be the cause for wetness in winter. As the water freezes inside the stone's pores, it expands (ice occupies around 9% more volume than water). In stones that have small pores this can have a similar effect like salt crystallisation: the ice exerts too much **pressure** onto the pore walls and the stone **cracks**, sometimes resulting in pieces of stone breaking off.[28] Outdoor limestone objects should therefore never be wet-cleaned in winter when there is a risk of frost.

Wind erosion is more of a problem with historic ruins and other large monuments that are regularly exposed to strong winds. The wind can directly **abrade** the stone's surface. With limestones, strong winds can further accelerate the problems associated with salt crystallisation and acid rain as they cause the stone to dry out quickly.[29] **Near oceans**, strong winds can transport ocean mist including high concentrations of sodium chloride salts to the object.

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[23] K.C. Normandin and D. Slaton. 2015. 'Chapter Eight: Cleaning Techniques'. In Henry, A. (ed.) *Stone Conservation: Principles and Practice*. Abingdon: Routledge: 129.
[24] Honeyborne 1998: 156.
[25] Honeyborne 1998: 156, Doehne & Price 2010: 11.
[26] Restorative Techniques. 2012. *Problems of Carbon Sulphation - Cleaning Properly Not Just Done Purely For Aesthetic Reasons*. Viewed 15. February 2021 <https://www.restorative-products.com/news/2012/problems-of-carbon-sulphation-cleaning-properly-not-just-done-purely-for-aesthetic-reasons>.
[27] Honeyborne 1998: 156, Durnan 2015: 164.
[28] Honeyborne 1998: 159ff.
[29] Honeyborne 1998: 164.

1.3.4. Biological Growth

Next to small animals like **birds** who may physically harm the object by picking on the stone to collect seeds and grit – with the additional risk of their **droppings producing harmful acids** – biological growth in the form of mosses, lichens, bacteria, fungi, moulds, and plants pose another risk for stone deterioration. **Most biological growth**, however, is **harmless** and might even serve as protective barrier against moisture and wind.[30] Their main effect will be aesthetic as biological growth often results in discolouration and obscuring parts of the object. Some types of mosses and lichens are protected by law.[31]

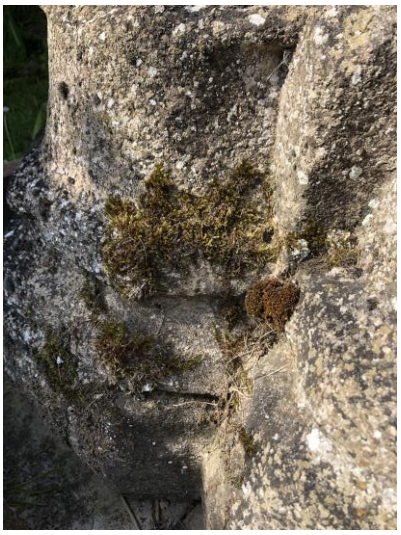
Yet, some types of growth may cause structural damage and other forms of surface deterioration:

- **Woody plants** can cause damage to the substrate since their roots can penetrate the pore system, in that way dislodging stone pieces.[32] But since limestone that is in sound condition commonly has a dense and fine-grained composition, plant penetration is usually poor and mainly superficial or along cracks and fissures.[33]
- **Mosses** are often superficial and may retain water to the surface thus exposing the stone to a constant supply of moisture that can cause or accelerate salt damage. On fragile surfaces, their roots may cause pitting.[34]
- **Algae** usually collect superficially and do not penetrate the stone. A thick layer that accumulates within joints and cracks, though, can create an environment that favours the growth of other organisms and woody plants. Some types of algae produce a type of slime that can expand and contract during wetting and drying cycles thus causing the stone's surface to flake or spall off.[35]
- **Fungi** are one of the most common organisms growing on stone objects. Their strands (*hyphae*) can penetrate stone surfaces to collect nutrients, at the same time secreting a small amount of acid that may cause damage to the limestone surface.[36]
- **Lichens** are a combined form of algae and fungi. Their hyphae can penetrate the surface and secret acids. They are slow-growing, and some rare forms can cause bleaching, blistering, or pitting.[37]

Mosses, algae, lichens, and fungi *are the main forms of biological growth on limestones.*
Remember: *Most organisms are harmless and might be protected by law. Is it really necessary to remove them?*

[30] J.A. Eklund. 2013. *Biological Growth on Masonry: Identification & Understanding*. Edinburgh: Historic Scotland: 2, Historic England. 2019c. *Conserving Stone War Memorials: Cleaning with Biocides.* Viewed 09. February 2021 <https://www.youtube.com/watch?v=Zp6obZuFhm0>, Doehne & Price 2010: 21.
[31] Eklund 2013: 6.
[32] Eklund 2013: 5.
[33] T. Warscheid and J. Braams. 2000. 'Biodeterioration of stone: a review'. In *International Biodeterioration & Biodegradation.* 46 (2000) 343-368: 345f.
[34] Eklund 2013: 3 & 5, Historic England. 2019a. *Reasons for Cleaning Stone War Memorials.* Viewed 09. February 2021 <https://www.youtube.com/watch?v=xQVUl_LfAQk>, Historic England 2019c.
[35] Eklund 2013: 4.
[36] Eklund 2013: 5.
[37] Eklund 2013: 5, Historic England 2019c.


Example of a gravestone (left) and a limestone building feature (right) with biological growth. Image courtesy of Dr. Emily Williams.



Example of moss growing on stone surface. Image taken by author with kind permission from *Burwell Museum & Windmill*.

Moisture is the main favouring factor for biological growth.[38] The extent of biological activity depends on the stone's composition and properties like porosity and roughness of its surface (many organisms seem to favour rougher surfaces over sleek ones).[39] **Reducing dampness and exposure of the stone is therefore the best approach to control biological growth**.

- Regular cleaning may further roughen the stone's surface thus creating even more favourable growth conditions.
- Some spores are always likely to survive any cleaning and will cause re-growth.[40]
- Susceptibility to cleaning techniques can vary from species to species, and many organisms' contribution to biodeterioration have scarcely been studied.[41] Hence, commercial products like biocides are often not efficient or will just bring short-term relief – not to mention their harmful effects on humans, the environment, or the object itself.[42]

Remember:
Protecting your object from moisture is the best way to control biological growth.

[38] Warscheid & Braams 2000: 344 & 349.
[39] Warscheid & Braams 2000: 344, Eklund 2013: 4, Historic England 2019c.
[40] Eklund 2013: 6f.
[41] Scheerer 2008: 189.
[42] Eklund 2013: 7, Warscheid & Braams 2000: 357, Scheerer 2008: 189.

1.3.5. Further Causes of Damage

Museum visitors always pose a certain degree of risk to objects: Next to vandalism, for example in the form of graffiti, they might accidentally stumble over objects on the ground, and they might touch objects, sit, or stand on them thus causing abrasion and soiling (e.g. from oily fingers, food, drinks etc.). Large numbers of visitors can increase temperature and relative humidity inside a room, thus accelerating the risk for salt damage.[43]

Another cause for object deterioration may be **inappropriate (past) treatments**. As described before, extensive exposure to water – for example through water cleaning – can cause salt damage, erode the surface, and pose long-term risks. Limestones are especially susceptive to acids as these have the ability to dissolve calcium carbonate (the main component of limestone). All kinds of chemicals, solvents, surface coatings, and biocides can be dangerous to the object if used by unskilled persons and should thus only be applied by professional conservators who have the equipment to do in-depth analysis of the soiling and the stone's composition and the experience and expertise on various treatment techniques.

Remember:
With the wrong cleaning product, limestone will dissolve. Imagine an effervescent Vitamin C tablet in water - the effect is just the same.[44]

Finally, **clay and mud inclusions** in the stone may readily pick-up moisture and swell, thus posing a risk for the stone to split.[45]

[43] Honeyborne 1998: 172.
[44] H. Jaeschke. 2021. E-Mail to S. Mueller on 10. February 2021.
[45] Jaeschke 2021.

1.4. Identifying Damage

The extent of deterioration can vary greatly from stone to stone as it depends on its chemical composition (what minerals are present and to what extent) as well as physical properties like porosity and texture.[46] A number of laboratory-based analytical techniques are available to conservators to identify damage, especially inside the stone, as well as its extent.

However, with **careful visual examination** many signs of damage like salt efflorescence, biological growth, fractures, fissures, cracks etc. can be detected also by untrained eyes.

Tips to Properly Examine Your Object:

- Examine your object in **appropriate lighting** (daylight rather than twilight, use a desk lamp if necessary).
- It can help to use a **magnifying glass**.
- If you have them try to compare the object to **old photographs** to see how features may have changed.
- **Document** everything you see:
  - Use a notebook, make little drawings, and take pictures to document everything that seems suspicious to you. Even if you are not sure what it is or whether it is harmful – you might be able to use your documentation to get advice from a stone conservator afterwards. Not only is documentation good practice, but you will also be able to determine the success of your cleaning and monitor any future changes.
  - Make sure to use some kind of scale in your drawings and photographs to indicate the size of the damage (if nothing else, holding a finger next to the damage may be a good solution).
  - Use good lighting, and make sure that what you want to photograph is clearly visible in your picture (close enough, captured in its entirety, not covered).
  - Be careful not to scratch the object with your scale, camera, pens, magnifying glass etc.
- **Take your time**: The longer you look at the object, the more you might see.
- Follow a **schematic approach** (e.g. from top to bottom, from left to right) to not miss out on areas.
- And as always: Practice makes perfect. With **experience** you will be able to easier detect irregularities and identify potentially harmful damage.

[46] Normandin & Slaton 2015: 132ff.

1.5. When to Contact a Professional Conservator

- When your object is **damaged or seems unstable** (shows cracks, breaking-off pieces, has a flaking, spalling, crumbling, or powdering surface). A professional conservator may be able to repair and consolidate any damaged areas. Do not attempt to glue pieces together yourself.

- When you are **not sure what kind of soiling** you have and whether it is harmful or might even be part of the object's history. It is always better to consult with a conservator who may have the appropriate tools to analyse the soiling and to advice on whether it should be cleaned or not.

- When you monitor your object over a certain time and observe **sudden changes** (e.g. salt efflorescence, new soiling of unknown origin, new fissures or cracks). A conservator may be able to identify the cause.

- When you are **not sure** whether you have the right plan or appropriate skills and tools to clean the object. It is always better to ask a conservator to revise your approach before irreversible damage is done.

Be aware that not every conservator is specialised in stone conservation. The best way to **find a specialist conservator** is **via local professional bodies**. In the UK this is the Conservation Register of *The Institute of Conservation* (Icon)[47] - the register is free to use -, in the United States the *American Institute for Conservation* (AIC)[48], and in Canada the *Canadian Conservation Institute* (CCI)[49].

In the UK, **museum development providers** can assist in finding funding information and in applying for financial help for your project. An overview of the current *Museum Development* providers can be found here: https://mduk.org.uk/programmes .

[47] Find a specialist conservator via **ICON**: https://www.icon.org.uk/resources/caring-for-your-collection/finding-a-conservator-you-can-trust.html
[48] Find a specialist conservator via **AIC**: https://www.culturalheritage.org/about-conservation/find-a-conservator
[49] Find a specialist conservator via **CCI**: https://www.canada.ca/en/conservation-institute/corporate/org-structure.html#a2e

2. Cleaning Techniques

2.1. Reasons for Cleaning & Potential Risks

You have thoroughly examined your object and detected soiling that you want to remove? Before you do so, always **question the origin of the soiling**. Is it recent dirt, or could it also come from the object's past use life, its manufacturing process, or could it even be traces of former surface decoration (paint, gilding etc.)? These are all **evidence of the object's history** and should not be removed. Some of it may not be clearly visible as it is obscured by dust and debris. Work carefully. You do not know what you might discover. If you are afraid that historic soiling or decorations might pose a risk to the object or hinder your cleaning approach, contact a stone conservator. They will help come up with a strategy.

You want to remove biological growth? Remember that most organisms are harmless, and some might even be protected by law.

Always **question your motivation** for cleaning. It is not appropriate to clean just to make the object look nice and shiny.[50] In fact, soiling may actually serve an object's **historic integrity** - why should it look like new when it is hundreds of years old?

Even when using appropriate cleaning techniques and tools there is a number of **risks** that cleaning poses, and they should be balanced against the wish to clean:

- **Surface damage and loss**: the object may look more stable than it actually is. If in doubt contact a stone conservator.
- Removing some encrustations and soiling can inevitably **remove original material** (e.g. the calcium sulphate crust on limestone caused by acid rain is a product of chemical alteration of original material).
- Deposition of **soluble salts** introduced by commercial products.
- **New staining** caused by water run-off.
- A freshly cleaned surface can make the object more **susceptible to pollutants and biological growth**.

Soiling and biological growth should only be removed if they are harmful to the object, visually obtrusive, or obscure important features like inscriptions or decorations.[51] Plan upfront what you want to remove, why, and to what extent. In most cases not the whole object will require cleaning and a **localised approach** may be the most appropriate – though be careful to avoid your object getting a patchy look of cleaned and uncleaned sections.

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[50] C. Willett. 2017. *Conserving War Memorials: Cleaning.* Edinburgh: Historic England: 5, Jaeschke 2021, J. Appell. 2010. *Cleaning Gravestones, Monuments & Stone Sculptures.* Viewed 09. February 2021 <http://www.gravestonepreservation.info/articles/cleaning-gravestones-monuments-stone-sculptures>.

[51] Historic England 2019a.

2.2. What to Consider Before Cleaning?

A number of points should be considered before cleaning. The following gives you a **checklist** that may need adding to depending on your individual objects and circumstances. The next sections in this guide will give you ideas on how to tackle these points:

- ☐ Make sure that you have **documented and photographed** the object before cleaning.
- ☐ **Have a plan** on what you want to remove, how, and to what extent. What is your goal?
- ☐ Manage your time. Cleaning **may take longer than you expect** as you take a cautious approach and might need to clean narrow crevices and carvings.
- ☐ **Where will you carry out cleaning?** Prepare cushioning under the object, make sure that it can be accessed from all sides to avoid extensive handling. Make sure that it is out of the way from people walking by.
- ☐ How do you plan to **collect dirt residues and water run-off**?
- ☐ Do you need **Personal Protective Equipment** (PPE)? Look at the information box below for some advice.
- ☐ Any cleaning technique should be **tested upfront** on a small and discreet area of the object to assess its efficiency, potential risk of damage, to manage expectations, and to plan how long the entire cleaning process will take.
- ☐ Plan to finish an object's entire side in one day once you start wet-cleaning to **avoid patches through irregular drying**.
- ☐ Do **not wet-clean outdoor objects in winter** when there is a risk of frost.
- ☐ **Photograph the object after cleaning and document your work**: What did you do? How did you do it? What materials did you use? Some damage may only become apparent in the long-term, and your documentation can then be helpful in finding a solution.
- ☐ **Know where you want to put the object once it has been cleaned** and prepare the area. Make sure that the object is not being introduced to the same damaging conditions again. See section 3 for advice on display and storage conditions.
- ☐ Stone objects – especially those displayed outdoors - can be **very heavy**. Carry them with several people or use appropriate lifting equipment. Before lifting, know where you want to place the object and make sure that your path has been cleared.
- ☐ _____
  _____
- ☐ _____
  _____
- ☐ _____
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Advice on PPE

Personal Protective Equipment (PPE) like gloves, lab coats, safety goggles etc. should be worn whenever there is a risk of the operator being harmed by cleaning products, residues on the object, or the object itself.

- Do not wear open-toed **shoes**, no high heels, etc. When handling heavy stones, consider wearing shoes with a steel cap.
- Wear **disposable gloves** when handling hazardous substances. Also, consider that some of the dirt on your object might be harmful (e.g. bird droppings – pigeons, for example, can transmit a range of diseases to humans), and that your object may have been treated with harmful substances in the past (e.g. biocides). Always cover cuts and wounds on your hands with a plaster and protect them with disposable gloves.
- Wear a **dust mask** (FFP3 is recommended) when cleaning heavy dust, mould, or fungi spores off your object. If possible, use a vacuum with a HEPA filter.

2.3. Dry Cleaning Methods

As you have seen in the previous chapters, water can do a lot of damage to limestone objects. It is therefore best to **start cleaning your object with dry methods** first. The following will remove dust, soiling and other loosely bound particles as well as superficial organic growth from your object:

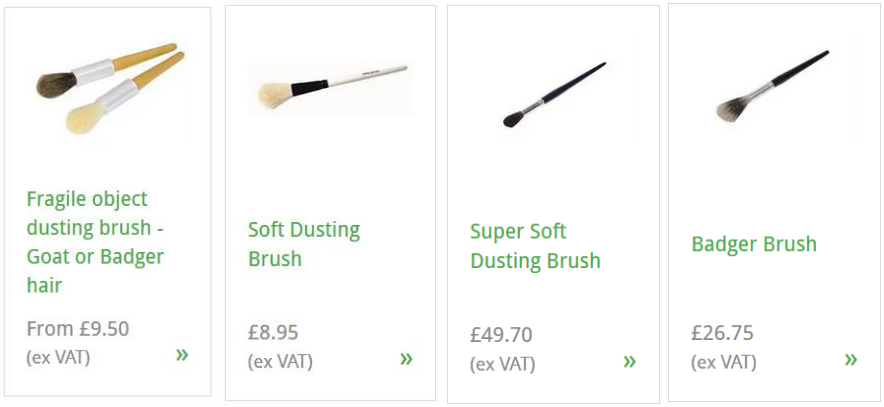
Brushes:

- ✓ **Soft bristle brushes** are available in various shapes and sizes. Have a couple of them at hand to choose the one that works best on large areas, small crevices, and around decorations. It is very important to use a soft brush as limestone can be easily scratched and damaged.
- ✓ **Cover the brush ferrule** (it is often made of metal) with masking tape or similar so that it cannot accidentally scratch the object.
- ✓ **Start with the softest brush** available.
- ✓ Plan how to collect the loosened dirt. Indoors a **vacuum on low suction** can be useful (a low suction is very important so you do not accidentally dislodge any stone pieces or decorations). Never use the vacuum directly on the object but hold it away a couple of centimetres. **Cover the hose** of your vacuum with a fine mesh to collect anything that may come off accidentally (and stop vacuuming and brushing immediately if parts of the stone's surface are crumbling off). The following video by *South West Museum Development* demonstrates this very well: https://southwestmuseums.org.uk/resources/cleaning-dry-methods.[52]
- ✓ Only use **clean brushes** so you do not contaminate your object with any unwanted substances.

[52] South West Museum Development Programme. n.d. *SWANS How-To Videos – Cleaning: Dry Methods*. Viewed 17 March 2021 <https://southwestmuseums.org.uk/resources/cleaning-dry-methods/>.

- ✓ **Work slowly and observe closely what is being removed**. Is it just dust and soiling, or is the stone's surface friable and easily removed by brushing? Are there any surface paints, gilding, or other decorations beneath the dirt layer? Do they come off with brushing? If so, stop immediately and consult a stone conservator to avoid losing parts of the original object.
- × **Never ever use wire brushes, steel wool, or other kinds of stiff brushes.** They will scratch and abrade the soft limestone surface and can do a lot of damage. Wire brushes may additionally leave behind small steel particles that can cause rust staining.

Brushes can be purchased in **art shops, hardware stores, and various online shops**. You might also have access to office supply shops and purchasing consortiums if you are part of a local authority or similar large organisation. The following products from PEL serve as references for what you should look for:



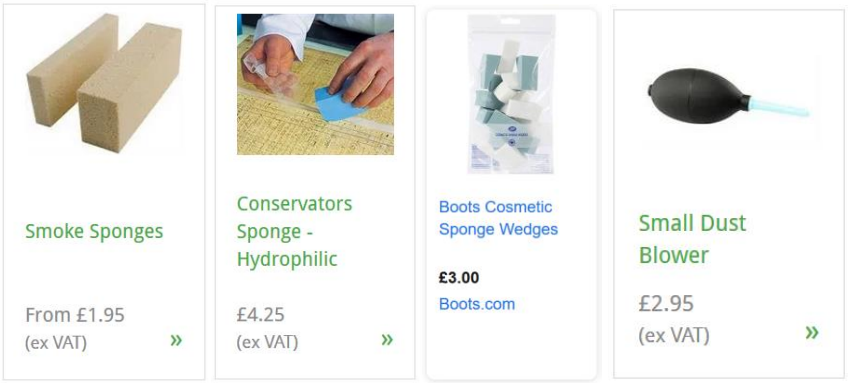
Source: PEL Online Shop.[53] Cheaper options are available in art shops and hardware stores.

Sponges:

- ✓ Sponges can be useful to **remove dirt and greasy deposits that are more adherent** to the object. Again, it is important to use a **soft sponge** like Smoke Sponge that is made of vulcanised natural rubber, microfibre sponges like PEL's Conservators' Sponge or cosmetic sponge wedges (made of polyurethane). They can all be cut into the shape and size that you need. Smoke Sponge can be made of synthetic material or latex (be careful with allergies and add a caution to your risk assessment for working with latex sponges).
- ✓ A **small dust blower** can be useful to remove sponge residues and debris as you go along.
- ✓ Once done, remove any sponge residues with a **soft bristle brush**.
- × **Do not use erasers, kitchen, pot, or cleaning sponges** as they can damage your object.
- × **Do not scrub** your object with the sponge. **Carefully dab the sponge across the dirty area** and it will pick up dust and soiling. The following video by Philatelic Preservation - albeit demonstrated on paper - shows this very well: https://youtu.be/zinsJ6F0Kuk.[54]

[53] PEL. 2021a. *Dusting & Cleaning Brushes*. Viewed 16 February 2021 <https://www.preservationequipment.com/Catalogue/Equipment-Tools/Brushes/ Dusting-Brushes>.
[54] Philatelic Preservation. 2014. *Dry cleaning paper with a smoke sponge*. Viewed 17 March 2021 <https://www.youtube.com/watch?v=zinsJ6F0Kuk>.

Useful products for cleaning with sponges:



Sources: PEL,[55] Boots.[56]

Removal of Biological Growth:

- ✓ Use **wooden picks, cocktail sticks, and wooden spatulas/tongue depressors** (they can be cut into the shape and size you need) to carefully level off superficial growth like mosses. Be very careful not to remove parts of the stone's surface. If roots go deeper into the stone, it may be better to leave them and just remove the visible parts of the organism.
- ✗ **Do not use any knifes, scalpels, gardening scissors or other types of blades and metal scrapers** as they can easily damage the object.

You can get toothpicks/dental picks, wooden spatulas, and cocktail sticks at a **local pharmacy** like Superdrug or Boots, **a supermarket, office supply stores, and from various online shops**.

Removing biological growth with wooden cocktail sticks. Left: Cleaning inscriptions (shown here is a granite stone, but the procedure for limestone is just the same), Middle & Right: Carefully separating moss and other superficial growth from the stone substrate. Left image courtesy of Dr. Emily Williams. Middle & right images taken by author with kind permission from *Burwell Museum & Windmill*.

[55] PEL. 2021b. *Sponges & Cloths*. Viewed 16 February 2021 <https://www.preservationequipment.com/Catalogue/Cleaning-Products/Sponges-Cloths>.
[56] Boots. 2021a. Boots Cosmetic Sponge Wedges. Viewed 16 February 2021 <https://www.boots.com/boots-cosmetic-sponge-wedges-10267856>.

When reading about dry-cleaning techniques, you may come across other options like sand- or grit-blasting, air-abrasion, power tools, or other abrasive techniques. Inappropriate use of any of these can lead to severe object damage and can also pose health and safety risks for the operator. Even if carried out in the most careful way it can cause material loss. Operators must be trained and experienced and will need appropriate PPE[57] – do not attempt to use any of these yourself.

2.4. Wet Cleaning Methods

Water can be very effective in removing stubborn soiling and staining.[58] But exposing your limestone object to moisture always bears the risk of salt movement, efflorescence, surface erosion, and can create favourable growing conditions for biological organisms. Damage sometimes only becomes apparent years later so it must be used with caution:

- ✓ Before you start cleaning, **test your chosen method on a small discreet section** of your object. Let it dry thoroughly and inspect the area closely for any potential damage. Has it become softer than the surrounding stone? Do you see staining?
- ✓ Always use clean water, ideally **deionised or distilled water** to avoid staining and contamination with mineral salts.
- ✓ Only clean **where absolutely needed**. In most cases it is not necessary to clean the whole object.
- ✓ Use **lightly dampened cotton swabs** (squeeze them out between your fingers). Apply them in a **rolling motion**, never rub them over the surface. Cotton seems to be soft, but its fibres can be quite scratchy on soft surfaces (often only visible under a microscope). The following video by *South West Museum* demonstrates this very well: https://southwestmuseums.org.uk/resources/cleaning-wet-methods.[59] To save money and make swabs as thin or thick as you need, use wooden sticks and roll small pieces of cosmetic cotton wool around one end. Use an old glass jar with a hole in the lid to collect used cotton. The toothpick can be reused multiple times.
- ✓ Soiling and dirt are often **softened** with a little water and can then be **removed easily with dry cleaning** tools (brushes, wooden picks etc.). No need to wet-clean until all soiling is gone.
- ✓ If you need to clean a larger area, use a **Fine Mist Sprayer with an adjustable nozzle**. This will keep the amount of water that your object is exposed to to a minimum and is much better controllable than larger volumes.
- ✓ Although this might be counter-intuitive, clean **from the bottom up** to avoid staining from run-off water as dry stone will readily absorb the dirty water.[60]
- ✓ **Immediately collect run-off water** with sponges, tissue, or cotton swabs to avoid new staining.
- ✓ **Regularly take a step back from the object** to make sure that your cleaning results look even.[61]

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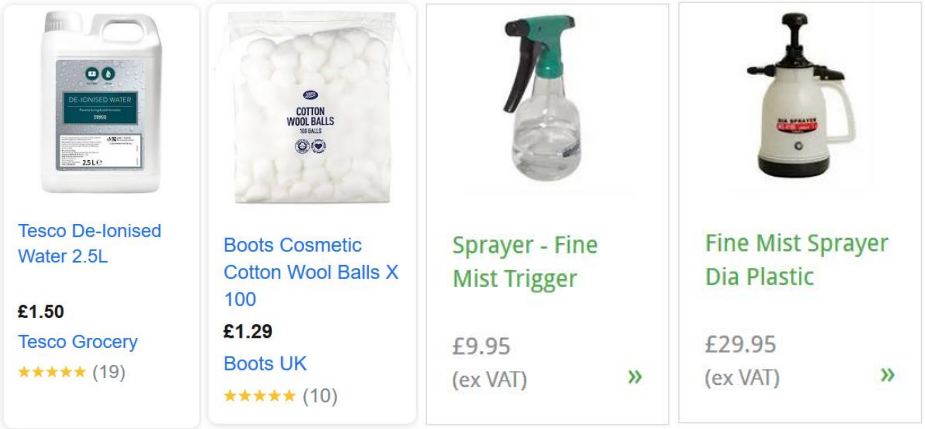
[57] Normandin & Slaton 2015: 147.
[58] Willett 2017: 8.
[59] South West Museum Development Programme. n.d. *SWANS How-To Videos – Cleaning: Wet Methods*. Viewed 17 March 2021 <https://southwestmuseums.org.uk/resources/cleaning-wet-methods/>.
[60] Appell 2010.
[61] Historic England. 2019b. *Conserving Stone War Memorials: Water Washing.* Viewed 09. February 2021 <https://www.youtube.com/watch?v=sGX9E_f5f00>.

- **Never use pressure washing**, not even low-pressure as limestone is soft and easily damaged by water hitting the surface. So, no gardening hoses and sprayers.
- **Do not add any chemicals or detergents** to the water to avoid staining and long-term damage.
- Water is an efficient solvent and **can dissolve historic paints and surface coatings**. Stop immediately if this begins to happen.

Remember:
Surfaces that withstand a short contact with water may become much softer with prolonged exposure.[62] Always use the least amount of water needed.

Materials you might find useful:



Sources: Tesco,[63] Boots,[64] and PEL.[65]

2.5. What to do if none of this is sufficient?

Remember your initial cleaning goal. What did you want to remove, why and to what extent? Is the soiling, crust, biological growth really harming the object or is it just an aesthetic issue? **Never aim for a nice and shiny "like-new" object.**

Take a step back: Your museum visitors will not be standing as close to the object as you currently are. If it is hardly visible from a 6-feet distance, then it is probably not necessary to remove.

If you are still not satisfied with the result or think the soiling might be harmful, contact a specialist conservator (see page 11 for contact details).

[62] H. Jaeschke. 2021. E-Mail to S. Mueller on 10. February 2021.
[63] Tesco. 2021. *Tesco De-Ionised Water 2.5L*. Viewed 16 February 2021 <https://www.tesco.com/groceries/en-GB/search?query=deionised%20water>.
[64] Boots. 2021b. *Boots Cosmetic Cotton Wool Balls x100*. Viewed 16 February 2021 <https://www.boots.com/boots-cosmetic-cotton-wool-balls-x-100-10111654>.
[65] PEL. 2021c. *Sprayers*. Viewed 16 February 2021 <https://www.preservationequipment.com/Catalogue/Equipment-Tools/Sprayers>.

2.6. Do's and Don'ts – A Summary of Limestone Cleaning

✓ **Consider why you want to remove something**
Is it really harmful? Could it be part of the object's history?

✓ **Only use soft bristle brushes and soft sponges**

✓ **If you need to use water, use blotted cotton swabs and gentle mist spraying only**

✓ **Use clean water only**
deionised, distilled

✓ **Use the minimum amount of water necessary**
For a minimum amount of time & exactly where needed
Test upfront

✓ **Remember that most biological growth is harmless and is best controlled when avoiding moisture**

✓ **Take your time, observe closely what you are removing** Stop immediately when you see any damage

✓ **Photograph and document your work**
Before and after cleaning

✗ **Do not aim for an "as-new" look**

✗ **Do not use wire brushes, steel wool, or other stiff brushes**

✗ **Do not use abrasives**
no power-tools, abrasive paper, etc.

✗ **No pressure water washing**
no garden hoses and similar

✗ **Do not use any chemicals, solvents, detergents, or other commercial products**
Dissolve your object, stain it, contaminate it with harmful salts

✗ **Do not use extensive amounts of water**
Softens your object, erodes its surface, favours salt damage & biological growth, can bring many long-term problems

✗ **Do not wet-clean when there is a risk of frost**

✗ **Do not remove biological growth that is protected by law**

✗ **Do not use any biocides**

3. How to Store and Exhibit Your Limestone Objects

Once you have cleaned your object make sure that it does not go back to the same potentially damaging environment where it comes from. A few simple measures can help to avoid or at least slow-down future soiling, biological growth, and other forms of deterioration:

Outdoors:

- Where possible, **raise the object off the ground** to avoid people stumbling over, and to avoid salt-laden moisture creeping in from the ground. This can for example be done by placing the stone on a bed of gravel.
- Have a **mud-free surface under the object** to avoid splashbacks. Make sure that **rainwater does not pool** around the object.[66]
- **Shelter your object from wind** as far as possible to avoid direct abrasion, increased drying rates, and to limit the impact of airborne salts.[67]
- Make sure that **roofs and tree branches do not hang over the object** as water may drip down, continuously eroding your object. Birds also like to nest under roofs and in trees, and their acidic droppings are harmful to limestone.
- As your object could contain organic components like paint pigments or coatings, **keep them out of direct sunlight**. Especially UV light can severely fade out any colours and cause cracking and embrittlement of surface coatings.[68] Limestone itself also is susceptible to heat and its structure may weaken upon exposure.
- **Keep plant growth away** and where this cannot be avoided cut the plants back regularly.
- If possible, **install a roof or shelter** to keep rainwater and direct sunlight away. Make sure that the roof is still protective when the sun is at its lowest point (Winter Solstice).[69]
- **Do not cover your stone with a polythene sheet or similar**.[70] This will create a micro-climate wherein temperatures can rise rapidly and condensation may be held against the object.

Example of a roof being built to protect the stones from rainwater and sunlight. Image taken by author with kind permission from *Burwell Museum & Windmill*.

- Keep **lawn mowers and grass trimmers** at a distance to avoid physical damage.[71]
- When using **water sprinklers**, make sure they are not directed at your object.[72]
- **Install a sign** to prevent visitors from touching the object. Where possible erect a **barrier**.
- Avoid using **de-icing salts** near your objects as much as possible.

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[66] Jaeschke 2021.
[67] Western Australian Museum 2017.
[68] D.D. Hartin, W. Baker, R. Barclay and G. Prytulak. 2018. Caring for outdoor objects. Viewed 16 February 2021 <https://www.canada.ca/en/conservation-institute/services/preventive-conservation/guidelines-collections/outdoor-objects.html>.
[69] Hartin, Baker, Barclay & Prytulak 2018.
[70] Jaeschke 2021.
[71] Hartin, Baker, Barclay & Prytulak 2018.
[72] Hartin, Baker, Barclay & Prytulak 2018.

Indoors:

- **Raise the object off the ground** to avoid people stumbling over.
- **Make sure that your object is kept away from acidic materials:** Oak wood, MDF (medium density fibreboard), plywood and chipboard often contain organic acids like formic and acetic acid[73] that can dissolve limestone. Display materials, storage shelves, but also historic wood objects are potential sources. Prevent your object from being in direct contact with potentially harmful materials, and do not place them together in a sealed display case or storage box. When using tissue or cardboard boxes to store your object, make sure they are acid-free.
- Make sure that your storage or display area has **good ventilation**, and that **relative humidity and temperature are kept as stable as possible**. Install a **datalogger** to monitor changes continuously, not just sporadic checks[74] as these will not indicate effects like heaters going on and off, opening and closing hours of the museum, daytime vs night-time conditions, rainy days vs sunny days etc.
- **Keep windows and doors closed** as much as possible on rainy days.
- **Keep your object out of direct sunlight and away from radiators and hot water pipes**. Light and heat can damage organic components and weaken the stone structure due to different rates of thermal expansion between salts and the limestone itself.
- **Maintain good housekeeping**: Regularly clean your storage and display areas to keep away nutrients that may attract biological organisms, and to avoid dust and grime to collect on your object.
- **Handle your object with gloves** to avoid salts, oils, and dirt from fingers to be absorbed into the stone due to its porous structure. Use nitrile gloves, not fabric, since fabric fibres might easily catch on the porous stone breaking off pieces. Where wearing gloves is not feasible (e.g. because the object is too heavy and you need a very good grip) touch the object with very clean hands only.
- **Keep handling to a minimum** to minimise the risk of accidentally dropping and breaking the object.

[73] L.R. Lee and D. Thickett. 2011. 'Selection of Materials for the Storage and Display of Museum Objects'. In Caple, C. (ed.) *Preventive Conservation in Museums*. Abingdon: Routledge: 243.
[74] Jaeschke 2021.

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APPENDIX – PRACTICAL GUIDE

Important Points

Practical Aspects of Limestone Object Cleaning

This practical guide is intended for those conducting the cleaning of limestone objects. For advice on the decision making of whether cleaning is necessary and what method might be most appropriate, please see the main guideline "Cleaning and Caring for Limestone Objects".

This Is Important

- Although stones are said to be hard materials and your object may seem to be difficult to break, bend, or deform, it can still be **soft and easily scratched.**
- Beneath the dust or dirt layer may be **traces of the stone's history in the form of tool marks, paint, gilding, plaster coatings etc. that must be preserved. Not all dirt is recent staining**. Be careful not to miss anything and consult with your supervisor when in doubt.
- Limestones are porous materials and **water can do a lot of damage** to them. Therefore, dry cleaning methods are to be preferred and if wet cleaning is necessary, follow the points below.
- **Document everything you do**. This is very important because cleaning can have long-term effects that are not immediately visible. Your documentation can then be helpful in finding a solution. Take notes on what you did, how you did it, and what materials you used.

Advice on PPE

Personal Protective Equipment (PPE) like gloves, lab coats, safety goggles etc. should be worn whenever there is a risk of the operator being harmed by cleaning products, residues on the object, or the object itself.

- Do not wear open-toed **shoes**, no high heels, etc. When handling heavy stones, consider wearing shoes with a steel cap.
- Wear **disposable gloves** when handling hazardous substances. Also, consider that some of the dirt on your object might be harmful (e.g. bird droppings – pigeons, for example, can transmit a range of diseases to humans), and that your object may have been treated with harmful substances in the past (e.g. biocides). Always cover cuts and wounds on your hands with a plaster and protect them with disposable gloves.
- Wear a **dust mask** (FFP3 is recommended) when cleaning heavy dust, mould, or fungi spores off your object. If possible, use a vacuum with a HEPA filter.

Dry Cleaning

How to Use Brushes

- Use the **soft bristle brushes** provided to you. Start with the softest brush available. Make sure that the **ferrule (often made of metal) has been covered** with masking tape or similar. Limestone can be easily scratched.
- Make sure that the **brush is clean** so that you do not contaminate your object.
- **Work from the top down** so that dirt does not get re-introduced into areas that you have already cleaned.
- If you are **indoors, use a vacuum on low suction** to collect dust and dirt. A low suction is very important so that you do not dislodge any stone pieces or decorations.
- The vacuum hose must be covered with a **fine mesh** to collect anything that may come off the stone accidentally.
- **Keep the vacuum at a distance** so that you do not accidentally scratch or hit the stone. **Stop vacuuming and brushing immediately** if parts of the stone's surface are crumbling off.
- **Work slowly and observe closely what is being removed.** Is it just dust and soiling, or is the stone's surface friable and easily removed by brushing? Are there any surface paints, gilding, or other decorations beneath the dirt layer? Do they come off with brushing? If so, stop immediately.

How to Use Sponges

- **Only use the soft sponges** provided to you. They can be cut into the size and shape needed.
- **Work from top to bottom** to avoid re-introducing dirt to areas that have already been cleaned.
- **Do not scrub your object** like you would for kitchen or bathroom cleaning. Carefully dab the sponge across the dirty area and it will pick up dust and soiling.
- If available, use a small dust blower to remove sponge residues and debris as you go along. Once done, **remove any sponge residues with a soft bristle brush**.

How to Remove Biological Growth

- Use **wooden picks, cocktail sticks, or wooden spatulas/tongue depressors**. You can cut them into the shape and size needed. Do not use knifes, scalpels, gardening scissors or other forms of blades and metal scrapers as these can easily damage the stone.
- **Carefully level off superficial growth** like mosses. Be very careful not to remove parts of the stone's surface. If roots go deeper into the stone, it may be better to leave them and to just remove the visible parts. Consult with your supervisor in this case.

Wet Cleaning

This Is Important

- Before you start cleaning, **test your method on a small discreet section** of your object. Let it dry thoroughly and inspect the area closely for any potential damage. Has it become softer than the surrounding stone? Do you see staining?
- **Always use clean water, ideally deionised or distilled water** to avoid staining and contamination with mineral salts.
- Only clean **where absolutely needed**. In most cases it is not necessary to clean the whole object.
- Soiling and dirt is often **softened with a little water and can then be removed easily with dry cleaning tools** (brushes, wooden picks etc.). No need to wet-clean until all soiling is gone.

How to Clean with Cotton Swabs

- Use **lightly dampened cotton swabs** (squeeze them out between your fingers). Apply them in a **rolling motion**, never rub them over the surface. Cotton seems to be soft, but its fibres can be quite scratchy on soft surfaces (often only visible under a microscope).
- To save money and make swabs as thin or thick as you need, **use wooden sticks and roll small pieces of cosmetic cotton wool around one end**. Use an old glass jar to collect used cotton. The toothpick can be reused multiple times.

How to Use a Fine Mist Sprayer

- If you need to clean a larger area, use a **Fine Mist Sprayer with an adjustable nozzle**.
- **Only use as much water as necessary** to soften and remove the dirt. **Water can damage the object** and by keeping the amount applied at a time to a minimum it is much better controllable than larger volumes.
- Although this might be counter-intuitive, clean **from the bottom up** to avoid staining from run-off water as dry stone will readily absorb the dirty water.
- **Immediately collect run-off water** with sponges, tissue, or cotton swabs to avoid new staining.
- Regularly **take a step back** from the object to make sure that your cleaning results look evenly.

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DISCLAIMER

This document is intended to offer informal advice and general guidance. It is not intended to be a substitute for the professional advice of a professionally qualified conservator. If in doubt, please consult with a professional conservator. The author and her partners accept no liability for the loss or damage which may arise if this guidance is followed. The author and her partners neither owe nor accept any duty or responsibility to any reader of this document, regardless of whether such reader makes use of the information provided in this document or not.

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