



BSI Standards Publication

Conservation of Cultural Heritage - Methods and materials for cleaning porous inorganic materials

National foreword

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English Version

Conservation of Cultural Heritage - Methods and materials for cleaning porous inorganic materials

Conservation du patrimoine culturel -
Méthodes et produits de nettoyage des
matériaux inorganiques poreux

Erhaltung des kulturellen Erbes - Verfahren
und Materialien für die Reinigung von
porösen inorganischen Materialien

This European Standard was approved by CEN on 29 July 2018.

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European foreword

This document ([EN 17138:2018](#)) has been prepared by Technical Committee CEN/TC 346 “Conservation of Cultural Heritage”, the secretariat of which is held by UNI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2019, and conflicting national standards shall be withdrawn at the latest by June 2019.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document calls for the use of substances and/or procedures that can be injurious to health if adequate precautions are not taken. It is recommended to read the relevant safety data sheets on the occupational and health hazards of the main chemical constituents of the products before using them. It refers only to technical suitability and this not absolves the user from legal obligations relating to health and safety at any stage. The manufacturer should also provide safety data sheets.

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Introduction

Cleaning is the removal of unwanted material from an object surface or near-surface.

The surface of an object is cleaned either for conservation and/or maintenance or to improve legibility.

A cultural heritage object is irreplaceable and while cleaning is undertaken for object conservation; its effects are irreversible. Failure to consider and address the technical problems which can arise during cleaning may cause irrevocable damage to an object. Cultural Heritage should be cleaned using the least disruptive/invasive procedure possible in order to best preserve it.

Furthermore, an inadequate or inappropriate intervention may cause, or increase, future deterioration processes or eliminate materials which are undocumented or which would allow a greater understanding of the history of the object.

Materials to be removed may include alteration products of the constituent materials, air particulate pollutants, dust, salt efflorescence; partially or totally soluble encrustations; layers of intentionally applied materials that are either inappropriate or no longer functional; biofilms; lichens; mosses.

Cleaning, as a part of the conservation plan, is based on the definition of which materials are to be removed and which materials to be preserved. In order to fulfil this task, the appropriate balance should be found among the following requirements: selectivity, effectiveness and controllability.

Before cleaning is carried out, it should be evaluated in terms of effectiveness and potential damage (harmfulness) by the use of trial areas. Evaluation should be continued during the cleaning operations and over the longer terms to monitor the effects of cleaning.

This framework document describes the cleaning systems providing a list of technical specifications useful for their selection, evaluation and optimization to allow proper and systematic evaluation.

Cleaning methods will be described according to a common structure:

- a) description;
- b) technical specifications (factors that define the system to be used);
- c) variables (factors that end users can adjust, control or change to optimize the process according to surface condition, the type and thickness of material to be removed, etc.);
- d) advantages;
- e) disadvantages;
- f) examples of applications (indicative situations in which the cleaning methods have been found to be effective).

This standard presents the methodology and requirements for cleaning particularly applicable to natural stone, ceramics, plaster, mortars and concrete. The presence of sensitive components, which may include certain stone lithologies or paint or other decorations on porous inorganic surfaces, for example, will preclude the use of some of the methods outlined in this document. The example applications given in the standard are indicative of practice and are not exhaustive.

The standard is intended to serve as guidance for all conservation professionals (architects, surveyors, conservators/restorers, conservation scientists, curators, etc.) involved in the conservation of objects. The standard is intended as a reference for organizations including government bodies and cultural heritage agencies, with a duty to preserve items of cultural heritage.

1 Scope

This document provides the guidelines for the choice of the operational cleaning technical specifications in order to optimize the cleaning operation. The fundamental requirements for each specific cleaning method are given as to adapt cleaning works for single specific cases.

The objective of cleaning may consist of removal of any combination of unwanted materials, such as: degraded protective coatings, surface or near-surface materials, which constitute a present or future threat to conservation, materials which prevent legibility of the object or are disfiguring by nature, deposits which are judged to be incompatible to the historical nature of the object.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1

porous inorganic material

material including natural stones, e.g. sandstone, limestone, marble, granite, gneiss, gypsum as well as artificial materials, such as mortar, plaster, brick, ceramics, concrete and others

[SOURCE: EN 15801:2009, 3.1, modified]

3.2

object

single manifestation of tangible cultural heritage

NOTE The term object is used in this standard for cultural heritage, both immovable and movable. In specific professional contexts, other terms are used: e.g. artefact, cultural property, item, ensemble, site, building fabric.

[SOURCE: EN 15898:2011, 3.1.3]

3.3

specimen

part considered representative of the material constituting an object

Note 1 to entry: The specimen can have different origins and can be taken from:

- materials similar to those constituting the object under study (e.g. stone quarries);
- specifically prepared comparative materials e.g. reference materials;
- available materials from the object.

Note 2 to entry: The number and dimension of the specimens can be different depending on constraints encountered in sampling the required amount of material.

[SOURCE: EN 16302:2013, 3.3]

3.4
cleaning

removal of unwanted material from an object

NOTE The criteria for something being “unwanted” can be stated, e.g. potentially damaging, obscuring detail, diminishes aesthetic value, etc.

[SOURCE: EN 15898:2011, 3.5.3]

3.5
water cleaning

cleaning including a series of different systems using water in liquid or vapour phase

3.6
nebulous spray
intermittent mist spray

development of low-pressure water washing, characterised by a mist spray entering in contact with the object surface

3.7
water spray at low pressure

spray based on the use of water at low pressure

3.8
abrasive cleaning

cleaning including all techniques that physically abrade the object surface to remove unwanted materials

3.9
dry grit blasting
sandblasting

dry blasting process delivering a stream of abrasive particles, under pressure, toward the object surface

3.10
microblasting
microsandblasting

dry blasting process delivering a thin stream of fine abrasive particles, under pressure, toward the object surface

3.11
wet grit blasting
hydro sandblasting

blowing of a mixture of water and grit toward the object surface

3.12
peeling system

cleaning method consisting of the application of a film forming product which can be peeled off to remove adhered particulate materials

3.13
steam cleaning

cleaning method where water vapour is used

3.14
aqueous poultices
packs

absorbent materials (non-reactive packs) mixed with water to form a paste which is applied to the object surface

3.15
biocide

substance able to kill micro-organisms, animals or plants colonizing porous substrates

3.16

biocleaning

cleaning using non-pathogenic micro-organisms to remove undesired substances (sulfates, nitrates, organic matter, etc.) from a surface

3.17

chelating agents

organic substances forming coordinate bonds with metal ions and producing a stable structure

3.18

cryogenic cleaning

dry ice-blasting

abrasive cleaning in which dry ice, the solid form of carbon dioxide (stable below $-78\text{ }^{\circ}\text{C}$), is accelerated in a pressurized air stream and directed onto the object surface

3.19

ion exchange resins

polymers (essentially) which contain ionic groups linked to their macromolecules by a weak bond and consequently have the ability to inter-exchange these groups with the ions present in the surrounding medium

3.20

laser cleaning

cleaning consisting in the removal of the unwanted surface materials from a substrate by using laser irradiation

3.21

surfactant

substance which lowers the surface tension of the medium in which it is dissolved, and/or the interfacial tension with other phases, and, accordingly, is positively adsorbed at the liquid/vapour and/or at other interfaces

3.22

toxic

substances and preparations which, if they are inhaled or taken internally or if they penetrate the skin, may involve serious, acute or chronic health risks and even death

NOTE See Directive 67/548/EEC.

3.23

toxicity

degree to which a substance is toxic

4 Requirements and general considerations affecting cleaning decisions

Cleaning should not be carried out unless necessary and when done it should be at the minimum level deemed effective.

The cleaning treatment should effectively remove both unwanted materials from the surface and/or in the bulk of the substrate (effectiveness) and should not increase the likelihood of future deterioration (harmfulness).

Therefore, to be a “conservation treatment” a cleaning method has to meet the following criteria:

- a) it should not raise the possibility that reactive chemical compounds have adverse reactions with the materials to be conserved, either immediately or in the future;
- b) it should not leave permanent or non volatile residues on or inside the object which might be harmful or have the capacity to change the morphology or the colour of the surface (for example efflorescences, stains, halos) either immediately or in the future;

- c) it should not cause physical - mechanical damage to the object (including erosion, loss of cohesion, detachment or formation of micro-cracks, increase of porosity);
- d) it should respect the original surface and finishes, and any subsequent additions with artistic or historic value (painting, patination, etc.) and/or original tool marks of the surface;
- e) it should maintain or, if possible, restore a level of surface topography comparable to that of the original surface;
- f) it should not be carried out in such way that it endangers the health of building occupants or workers; therefore the possible toxicity of the products shall be taken into account; as well as the possible toxicity of waste requiring removal to appropriate storage sites;
- g) it should minimize the risk of damage to any personal or public property;
- h) it should require that due consideration is taken on the practicalities of treatment in order to minimize potential problems with efficiency and application.

As no building, no environment, no object, no deterioration history is necessarily identical it is anticipated that solutions will differ. A number of different decay features may occur on an object which necessitates deployment of various methods.

Each conservation project should be considered carefully, taking into account previous experience with the object (or similar objects) and available materials and methods which might be useful but should not be assumed to apply fully in every case.

Some deposits are not fully removable from surfaces without causing excessive damage. In this case, residual or uneven marks may remain and do not necessarily indicate poor quality cleaning.

Methods which allow careful control and evaluation and which may be readily halted by the operator are favoured.

The efficacy of each method should be evaluated for each specific situation. Preliminary laboratory tests are intended to define the potential danger as well as the likely effectiveness of the method for each type and condition of porous materials. Special attention should be paid to the chemical and physical nature of the product used, for the cleaning process, the methodology and the duration of the application. Methods and products which are harmless in some cases, may cause damage on other materials or on the same material if applied incorrectly.

In case of well-consolidated materials, cleaning is usually the first operation to be carried out. Where objects are in an advanced state of decay or naturally lack of cohesion, pre-consolidation of the material and protection of the surface with a sheet of Japanese paper prior to cleaning should be considered. It should be noted that such a treatment may influence the eventual choice of the cleaning method, and it may become more difficult to eliminate any biodeteriogens, for example cyanobacteria, algae, lichens and mosses and others unwanted materials deeply penetrated within the substrate. Original paint/decorations should always be retained.

In the case of carved surfaces, or any other surfaces of any particular historical and/or artistic importance, scales and fragments of the original surface should be retained *in situ*, wherever possible, and not deliberately removed.

It should be noted also that the end result of cleaning will depend both on the knowledge and capacity of the conservator/restorer, the effectiveness of the materials and methods adopted.

5 Preliminary investigation to optimize cleaning selection process

5.1 Preliminary survey

5.1.1 A preliminary survey should be carried out according to [EN 16095](#) and [EN 16096](#), particularly taking into account the following items:

- a) historical information of previous conservation intervention (cleaning/treatment);
- b) description of the nature of the constituent materials and their location on the object by visual inspection, which may include additional investigations where finishes may be present;
- c) description and mapping of the different forms of deterioration by visual inspection;
- d) description and localization of the effects of previous cleaning operations and other interventions if they are detectable by visual inspection;
- e) study of environmental context. A full understanding of the context of the site should be obtained to identify and minimize any environmental decay factors, which may arise from the cleaning process;
- f) identification of potential test areas;
- g) background information on susceptibility of substrates as a preliminary guidance for the selection of cleaning methods;
- h) search for evidence for former paint layers.

5.1.2 Records should be kept of all operations on object of significance including:

- a) photographs of the object showing its condition and appearance before cleaning is carried out;
- b) drawings of the different materials constituting the cultural heritage object;
- c) drawings of unwanted materials location, thickness and nature; and current condition of the object.

Specific phenomena should be characterised and a description given with the images to provide an ongoing record. This may be done with reference to an existing visual glossary which should be stated.

When non-invasive methods are not available or are unable to provide the necessary information, samples for laboratory analyses should be taken, where possible. These samples are required in order to accurately identify the materials and the deterioration products and consequently to select the most appropriate cleaning method.

5.2 Identification of substrate and characterization of unwanted materials

5.2.1 Following preliminary survey, objects to be cleaned should be inspected closely and analysis/tests should be carried out using the following procedure:

- a) each constituting material should be identified in sufficient detail so that cleaning can proceed while minimizing risk to the object. The knowledge of the chemical, mineralogical and structural characteristics of the material constituting the object and the properties of the substrate close to the external surface, are important. This is a more accurate assessment of item [5.1.1](#) b);
- b) the condition of the object and associated materials should be assessed and mapped (digital record), as well as the nature and effects of previous treatment operations, (see [5.1.1](#) c) and d);
- c) the extent, nature, thickness and distribution of materials to be removed should be identified. The layer of unwanted materials and the altered surface of substrate should be distinguished from each other at the investigation stage, so that the level of cleaning can be selected;
- d) the presence of surface working and or intentional stratification such as finishing, painting and polychrome layers should be identified;
- e) assessment, by means of preliminary laboratory tests, of the effectiveness and harmfulness over the immediate and long term perspectives of the cleaning products and procedures to be used on similar materials.

5.2.2 Unwanted materials on object surfaces can vary from a few microns to some millimetres in thickness and cleaning can involve removal of one or more of the following materials, reported as the more common examples:

- a) atmospheric particulates, often bound together as well as to the object surface and composed either of calcium sulfate, calcium carbonate or silica, depending on the substrate;
- b) biofilms composed by heterotrophic bacteria, cyanobacteria, algae, fungi, lichens;
- c) mortar splashes and runs;
- d) encrustations of calcium carbonate;
- e) efflorescent salts;
- f) bird droppings;
- g) paint and graffiti;
- h) bird repellent gel;
- i) oils, grease and waxes;
- j) stains;
- k) soiling or earth encrustations on archaeological items;
- l) overpaints;
- m) anti-graffiti coatings;
- n) previous treatments or reaction products derived from previous treatments.

5.2.3 Records should be kept of previous operations on object of significance including drawings (photographs or analyses) of:

- a) the different materials constituting cultural heritage object if different from [5.1.1 b\)](#);
- b) the extent, nature, thickness and distribution of materials to be removed and of the condition of the object, if different from [5.1.1 c\)](#) and [d\)](#);
- c) the surface finishes or tool marks, painting and polychrome layers;
- d) the sampling location, if applicable.

Specifications and other documents that might be required for a cleaning project should be prepared in sufficient detail to give a proper guidance in the preparation of estimates and execution of the work. Copies of all relevant documents should be available to all parties involved, including site personnel responsible for supervision. Documents should be retained to provide background information prior to further assessments or work. Following these surveys the decision on which, if any, cleaning methods are appropriate, should be made.

6 Selection of cleaning methods

Following the preliminary survey and the identification of the substrate and unwanted materials (see [5.2](#)) an appropriate cleaning method should be selected among those reported in [Clause 8](#).

As a cleaning process may involve multiple applications of one system or several removal systems *in situ* trials should be carried out on representative areas

Efficacy and suitability of the products and procedures (see [Clause 7](#)) tested, shall be subject to preliminary evaluation.

As a single object can consist of a complex assemblage of features differentiated by their physical and chemical properties, the expertise of a team of professionals, each one specialized in a defined field of knowledge may be required to produce a conservation plan which uses several different products and procedures.

7 Trial cleaning areas

The aim of cleaning a trial area should be to determine:

- the suitability of the cleaning method for the object, its condition, and the unwanted materials;
- the degree of cleaning that can be achieved, and its acceptability.

Cleaning processes should be pre-tested on surfaces of the object representative of all those on which cleaning will be performed. If possible, test areas should be located in unobtrusive locations, and in any case should be small in case the decision made after the trials is not to proceed with full scale cleaning.

When trialling different cleaning methods those which are (seen as / predicted to be) least aggressive shall be tested first. Progression towards methods which are more aggressive should be made only if necessary.

A detailed record should be kept of trial cleaning and the location of trial areas.

This should be retained for reference throughout the duration of the cleaning process.

Trial cleaning should be observed and assessed by persons responsible for preparing the cleaning specification. Trial areas should be available for inspection by relevant authorities.

Trial cleaning should be agreed beforehand, and carried out by trained and experienced specialists conversant in a variety of cleaning systems.

When useful, trial areas should be assessed in wet and dry conditions.

Full assessment should include:

- a) potential damage to the object as a result of cleaning;
- b) colour changes resulting from the cleaning process;
- c) the general appearance change of the object surface after cleaning;
- d) the efficacy of the removal of unwanted materials.

8 Cleaning methods

8.1 Water cleaning

8.1.1 General

Water cleaning includes a series of different systems using water in liquid or vapour phase.

Water can be supplied in different forms as mist of droplets, spray, steam etc. or contained within a gel or poultice medium.

The solvent action of water is mainly influenced by temperature and specific surface of the droplets coming into contact with the object surface. In addition to the solvent action a mechanical effect is also present, due to the water contact pressure.

If the condition of the surface allows it, the action of the water spray can be augmented by a gentle mechanical action, using, for example, nylon or bristle brushes.

Before selection of any one of these methods, the porosity and condition of the material shall be assessed in order to balance the amount of water and duration required.

Special consideration should be given to areas where the materials change, for example at mortar joints

The conductivity of the water used shall generally be less than 400 $\mu\text{S}/\text{cm}$, a level at which most tap water will be suitable for cleaning.

In case of historical building some preliminary works should be considered prior to cleaning such as temporary pointing or filling of any cracks that would let cleaning liquids enter the wall or the building interiors. Glazing and window frames shall be protected with plastic foils and tape. Vulnerable items or materials within the location shall be protected within the cleaning area if applicable.

Before cleaning the exterior of a building, the building's rainwater drainage system shall be inspected to ensure that it is of sufficient capacity, in good condition and free from blockages. Water-based methods shall not be used if there is a risk that outside temperature will fall below 5 °C (risk of frost formation) during cleaning and until the material is sufficiently dry following cleaning to reduce possibility of frost formation.

Water run-off must be managed and contained.

8.1.2 Nebulous spray or intermittent mist spray

8.1.2.1 Description

Nebulous spray, also known as intermittent mist spray, is a development of low-pressure water washing which is often considered to be the least aggressive form of cleaning.

The system of nebulous sprays is based on the principle of passing water through a very fine mesh or filter to create a mist, which is then passed through fine nozzles. The action of the mist swirling across the surface of the object dampens and softens the dirt layers. The action of the mist also activates mobilization of the dirt particulates and thus breaks the cohesion of the dirt layer and the adhesion to the substrate underneath.

The aim of nebulous spray is to apply the lowest amount of water for the minimum duration in order to soften the dirt, thus enabling its removal by scrubbing or other relatively gentle mechanical cleaning.

The position of the nozzle with respect to the surface to be cleaned should be carefully controlled to prevent any mechanical action from the water droplets, as cleaning method should only work through the process of solubilisation. To reach this purpose the jet of nebulised water should not directly hit the surface to be cleaned, but should reach the surface as it begins to fall downwards.

A number of spray heads or nozzles are mounted on a boom arm in front of the area to be cleaned. These are attached by a hose to the water supply.

Placing nozzle heads on booms allows the flexibility to create the mist to facilitate cleaning wherever this is required. Enclosure within a protective waterproof covering aids the cleaning process as it prevents interference from external weather conditions.

In order to prevent any migration of contaminated water to lower levels, a proper collection and disposal system for waste water shall be installed.

The water shall be nebulised, at the ambient temperature, using hydraulic atomizing nozzles which produce a fine mist-like spray in the form of a hollow cone. The recommended diameter of the orifice is less than 1 mm which is capable of producing droplets with diameters varying from 80 μm to the maximum recommended size of 120 μm . The dimensions and distribution of the droplets can be determined by using appropriate hydro-sensitive papers.

Every 15-20 min, the extent of cleaning should be checked to guarantee a homogeneous application appropriate to the specific treatment for the material to be removed.

The amount of water may be controlled electronically or by timers, allowing pulse or intermittent spraying, to avoid ever having water running down the object surface.

The system should be designed to be highly flexible, directing the spray only where needed.

The following are indicative of some methods by which the system can be customized:

- a) the nozzles from the hose may be grouped or spaced according to condition of the surface and to the severity of the dirt or encrustation being treated and condition of surface;
- b) flat surfaces require less water than a heavily soiled carved detail, which may require a cluster of nozzles positioned on an articulated hose to the profile of the carving;
- c) the sprays are also operated on an electronic cut-off system. This is run in conjunction with sensors located below the area being cleaned. When the required amount of water determined by trial areas, has been deposited on the wall, and therefore the sensor, this will switch off the supply of water to the nozzle arms;
- d) an intermittent spray system, whereby a short period of spraying is followed by an extended period where there is no spray, is used in order to confine the action of the spray to outer layers.

The cycle adopted is strongly dependent on the physical characteristics of the object substrate and its condition.

8.1.2.2 Technical specifications

- a) hydraulic nebulizing nozzles orifice diameter of: 0,4 mm to 0,8 mm
- b) average droplets diameter: 80 μm to 120 μm

8.1.2.3 Variables

Depending on the kind of surface, the variables below listed shall be fixed according to the type and thickness of dirt to remove and according to the surface condition, following tests on trial areas:

- a) specific conductivity of water (for some applications deionized water less than 50 $\mu\text{S}/\text{cm}$ is recommended);
- b) water consumption (l/hour);
- c) distribution of droplets (visual assessment);
- d) distance between the nozzle and the surface (cm);
- e) spatial arrangement (orientation and density of the nozzles-number/ m^2);
- f) duration (minutes) of each wetting and drying phase and number of cycles (wet+dry).

8.1.2.4 Advantages

- a) The impact of the mist on the surface is negligible, reducing the risk of mechanical damage unless the surface is extremely disaggregated.
- b) Thicker encrustations of soiling which tend to form in protected areas of an object, which are not regularly washed by rain, may be softened by the water and subsequently mechanically removed.
- c) Encrustations and soiling are softened progressively which allows control over removal reducing the risk of over cleaning.
- d) Compared to other water-based washing systems, a mist spray uses less water, so avoiding the excess run off to adjacent areas of the surface.

- e) Removing softened material by brush between spraying cycles may accelerate the cleaning process and has the added advantage of enabling progress to be monitored.
- f) The water presents fewer hazards to the public and operators, than some other methods.

8.1.2.5 Disadvantages

- a) This method is not effective for the removal of soiling or staining which is insoluble in water.
- b) Water cleaning with nebulous spray or intermittent mist spray is not recommended for porous inorganic material with a high water absorption capacity, for weathered surfaces and for a salt rich substrate. Water cleaning methods may exacerbate deterioration when used on badly deteriorated surface and may induce dangerous dissolution/recrystallization cycles when rich salt substrate is present.
- c) A frequent problem with many limestones and some sandstones is the formation of brown or orange staining caused by naturally occurring iron compounds within the stone being mobilised and carried to the surface.
- d) The risk of water penetration through defective joints or fractures is still present with the nebulous spray system, illustrating the importance of carrying out a thorough survey externally, and continuous monitoring of the interior as cleaning progresses. Despite the relatively low water volumes, water penetration to the interior of the building may sometimes occur.
- e) The method cannot be used when water sensitive original materials are present, including wall paintings.

8.1.2.6 Example of applications

Its application is particularly useful on building façades where unwanted water-soluble materials are present.

This method works well on thin soiling layers which are sensitive to water. Water cleaning by nebulous spray has been historically used extensively for the cleaning of marble and low porosity limestone, as the soiling is generally bound to relatively soluble compounds.

In some cases, cleaning may be less efficient on siliceous stones, such as granite or sandstone, where the soiling is bound to the silicate surface as insoluble compounds.

Where the use of more invasive cleaning methods is inevitable, the use of nebulous spray system to pre-soften the dirt may be beneficial.

8.1.3 Water spray at low pressure

8.1.3.1 Description

The method is based on the use of a water spray system based on the principle of passing water through nozzles thus creating droplets which impact on the surface of the object. Water at low pressure (0,2 MPa to 0,3 MPa) is used.

Fan or cone jet nozzles of 25 degrees minimum should normally be used for low pressure washing (hot or cold water). Water pressure and type of nozzle should be adjusted as applicable to the substrate condition.

Rotating nozzles should be used for rinsing inside the recesses of complex surfaces (e.g. carvings).

Pressure, angle and nozzle distance from the surface should be carefully controlled.

Cleaning should be carried out by wetting and softening (rather than by mechanical action of the water).

Pressure cleaning systems which use a medium to high pressure through a mechanical sprayer to remove the unwanted materials from the surfaces of buildings are not considered in this clause. The medium or high pressure washing and hydroblasting (very high pressure washing) are not recommended for cleaning of cultural heritage objects.

8.1.3.2 Technical specifications

- a) nozzles orifice diameter: 1mm to 2 mm
- b) water pressure: 0.2 MPa to 0.3 MPa max

8.1.3.3 Variables

- a) Distance between the water outlet and the surface;
- b) angle of direction of the nozzle;
- c) water consumption.

8.1.3.4 Advantages

Low cost. Does not require highly specialist equipment.

It is effective in removing water soluble dirt from materials of low porosity (e.g. concrete, cement-based renders, some brick type, cast stone etc.).

8.1.3.5 Disadvantages

In addition to those reported for [8.1.2.5](#) a), b), c), d), e), the following have to be taken into account:

- a) Large amounts of water, higher than that used with the nebulous spray, are potentially hazardous to buildings and proper precautions and supervision should be provided so that water does not enter core material,
- b) temporary catchments and gutters should be provided to efficiently remove water from the building walls and to avoid over-saturation at lower levels, and dispose of it in an appropriate manner,
- c) the impact of these techniques on disintegrated surfaces will cause loss of material.

8.1.3.6 Example of applications

This technique can only be applied on surfaces in very good condition (e.g. monolithic concrete).

8.1.4 Injection extraction cleaning

8.1.4.1 Description

The injection-extraction method is based on a specific vacuum-washing technology. Water is sprayed on the soiled surface through a head which also recovers the dirty water by a suction action. The cleaner nozzle is fitted with a soft bristle brush and protected with a soft plastic joint to be moved over the surface without damaging it. A surfactant in low concentration can be added in order to enhance the wettability.

8.1.4.2 Technical specifications

- a) Water pressure: 0,2 MPa to „0 MPa;
- b) suction vacuum: 34 kPa $\pm$ 4 kPa.

8.1.4.3 Variables

- a) Water consumption (l/hour);
- b) surfactant addition (%).

8.1.4.4 Advantages

Cleaning is based on water effect (dissolution and leaching) but the surface is wetted very slightly and almost instantaneously dried. Specifically designed devices allow the application on a large variety of surface constructions. Tool heads of different widths and shapes are available to allow the application on more or less regular, relatively flat surfaces.

The water is confined: the solution and the dirt are vacuumed off into a tank, no waste water runs down the walls and ceilings.

The environment does not require any great protection against water, dust, noise; the site can continue to be used (e.g. church, office, stairs...).

8.1.4.5 Disadvantages

- a) The system is designed to be used on flat surface, so it is extremely difficult to use it on highly contoured surfaces.
- b) The risk of water penetration through defective joints or fractures is present.
- c) A frequent problem with many limestones and some sandstones is the possible formation of brown or orange staining caused by naturally occurring iron compounds within the stone being mobilised and carried to the surface.
- d) The system does not allow sufficient time to soften or dissolve soiling.

This method is not recommended for:

- e) fragile surfaces due to the risk of loss of material;
- f) removal of soiling or staining which are insoluble in water;
- g) stone with a high open integral porosity and for weathered surfaces;
- h) salt rich substrate due to the occurrence of dangerous dissolution/recrystallization cycles.

8.1.4.6 Example of applications

The method is suitable to remove loose deposits (e.g. soot deposits) which are frequently present on indoor walls (concrete, brick and stone wall masonry, plaster, etc.).

8.1.5 Steam cleaning

8.1.5.1 Description

Most steam cleaning equipment produces a biphasic system where the vapour phase is in a dynamic equilibrium with the liquid phase.

The equilibrium is mainly influenced by temperature and pressure.

Most steam cleaning equipment produces wet steam, in which there are also a few droplets of hot water. The pressure comes from the steam generation process itself. As the vapour is generated, the pressure inside the container increases; steam at about 150 °C remains in liquid phase as long as the pressure in the container is above approx. 0,4 MPa. By releasing the pressure when opening the nozzle, the liquid water will vaporize into steam and cool down to the boiling point of water at atmospheric

pressure (100 °C). By doing so, it expands about 1,5 times. This expansion occurs in the nozzle and helps to provide the pressure of the steam. The temperature of the steam tends to drop quickly after the vapour exits the nozzle and some of the vapour will condense into water droplets. Steam cleaning using such equipment is achieved by a combination of steam and the few droplets of hot water.

Whilst the temperature in the system is high, the pressure on the surface being cleaned is very gentle and the volume of water is low. The surface is therefore not saturated and will be dry within minutes.

There are many different kinds of steam cleaners available on the market and they should be clearly distinguished from hot water washers.

The small industrial steam cleaning machines that are used in conservation emit very small quantities of water; typically 2 l to 4 l of water per hour at a working pressure of 0,2 MPa to 0,6 MPa through a hand-held nozzle. This type of steam cleaning equipment offers the advantage of using less water than most other cleaning processes, which may be advantageous in regard to the nature and condition of the substrate or constraints on the site or location.

Larger systems are available which have higher working pressures however their use on cultural heritage is not recommended.

The operator shall carry out preliminary trials to ascertain the optimum technical specifications and variables (selection of equipment, pressure level, temperature, nozzle type and cleaning process) that best suit the type and condition of the substrate and the specific type of soiling.

In general, the wider the spraying angle, the lower the pressure at the surface of the substrate. A spraying angle of 40° is normally used. A narrower angle can result in a higher pressure that may be sufficient to cause damage to soft or decayed limestone and sandstone.

Nozzle selection plays an important part in planning of the cleaning process and the way in which the steam cleaning works. A range of spraying shapes and angles are available. Most commonly used are the solid cone (suitable for carved surfaces) and the fan shape (suitable for cleaning larger areas of flat ashlars). These different types of nozzles also have different properties in terms of the diffusion temperature of the jet of steam; for example, a standard nozzle may lose sharpness at temperatures above 140 °C. This variable can be used to control the precision and effectiveness of the jet.

It is recommended that the nozzle is not placed too close to the surface of the object as this may result in damage to the surface and an uneven cleaning.

In many cases, the best cleaning is achieved using a double-step technique. The first step is performed at a lower pressure and will soften the soiling. After a while (from minutes up to a few hours established by trial areas) the softening will have happened and a second step will now allow the soiling to be removed more completely and without the need for the nozzle to be held too close to the surface.

8.1.5.2 Technical specifications

- a) Spraying angle: around 40°;
- b) working pressure: 0,2 MPa to 0,6 MPa.

8.1.5.3 Variables

- a) Nozzle type;
- b) water consumption (l/hour);
- c) working distance (cm);
- d) duration of the contact.

8.1.5.4 Advantages

In comparison with hot water washers steam cleaning uses much less water and therefore the process is easier to control and any secondary damages more easily avoided. However, recent technological developments in the use of vacuum heads that both deliver the steam to the surface and collect the residue enables its use also in sensitive environments and allows the operator to have the full overview of the process.

The way in which a steam cleaner is used by the operator can make a significant difference regarding the cleaning effectiveness.

8.1.5.5 Disadvantages

- a) As many substrates are very sensitive to the relative high temperature of the steam its use is restricted to few materials and for removal of specific unwanted materials.
- b) It is generally not suitable for brittle soiling such as calcium sulfate, which, in any case, is less soluble in hot water than in cold.
- c) The steam generated does not allow the operator to immediately see the result of material removal.
- d) In closed spaces, the increase in humidity may necessitate increased ventilation.
- e) There will usually be some water run-off which will need to be collected usually by means of a sponge held beneath the nozzle.
- f) It is not recommended for cleaning of fragile surfaces because the high temperature of the steam can damage the porous inorganic material and effects cannot be controlled.
- g) It is not recommended in the presence of soluble salts.

8.1.5.6 Example of applications

This type of cleaning may be used on marble, low porosity limestone, granite, gneiss.

Generally, it may be used to remove indoor soiling, soot, microbiological growth (e.g. algae, lichen and moss) and unwanted layers including wax and greasy materials, paints with no historic or artistic value, glues and materials from former restorations.

8.1.6 Aqueous poultices or packs with absorbent material

8.1.6.1 Description

Aqueous poultices or packs with absorbent materials (non-reactive packs) contain water and the medium only, relying on these ingredients to achieve the mobilization and removal of the unwanted materials. They are often called true or plain poultice.

The poultice medium or packs are described in [Annex A](#).

The properties of the final poultice/pack may be achieved by combining any substances.

Consideration should be given to the chemical composition and microstructure (for example dimension of the particles or the fibres) of materials used as the solid matrix. In all cases the materials shall be free from soluble salts.

Whatever the medium, the poultice is mixed with water to form a material that will adhere to the substrate. Clay forms a sticky mass that adheres well to the object surfaces. These plain poultices can be conveniently mixed by hand as required on site with the addition of water to the poultice medium.

As clay forms a sticky mass its use may be inappropriate where the surface has open pores or is badly deteriorated (often the case with limestone or sandstone sculpture), and paper or cotton fibres may